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Supplement to

Appendix to the Journal of the Senate

LEGISLATURE OF THE STATE OF CALIFORNIA

1956 REGULAR SESSION

Convened March 5, and Adjourned April 3, 1956

REPORTS

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President of the Senate

HON. BEN HULSE
President pro Tempore of the Senate

J. A. BEEK
Secretary of the Senate

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SUPPLEMENT TO SENATE JOURNAL APPENDIX

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Water Problems, Joint Committee on
Eighth Partial Report—Report on Engineering, Economic and Financial Aspects of the Feather River Project by Bechtel Corporation

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EIGHTH PARTIAL REPORT ON

WATER PROBLEMS OF THE STATE OF CALIFORNIA

Report on the

Engineering, Economic and Financial Aspects Of the Feather River Project

TO THE

JOINT COMMITTEE ON WATER PROBLEMS
CALIFORNIA STATE LEGISLATURE

BECHTEL CORPORATION
SAN FRANCISCO, DECEMBER 31, 1955

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RICHARD RICHARDS	JACK SCHRADE

MURRAY R. MacKALL, Executive Secretary and Consultant
Committee Office: 613 State Building, San Francisco

Published by the
SENATE
OF THE STATE OF CALIFORNIA
HAROLD J. POWERS
President of the Senate

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Secretary

March, 1956

LETTER OF TRANSMITTAL

SENATE, CALIFORNIA LEGISLATURE
March 6, 1956

To the President of the Senate,
the Speaker of the Assembly,
and to Members of the Senate and Assembly

The Joint Committee on Water Problems, created pursuant to Senate Concurrent Resolution No. 84, Resolutions Chapter 249, Statutes of 1955, under authority of and pursuant to Senate Concurrent Resolution No. 42, adopted in Senate April 28, 1955, and in Assembly June 8, 1955, Resolutions Chapter 253, Statutes of 1955, and under authority of and pursuant to Joint Rule No. 37, entered into a contract as of August 19, 1955, with Bechtel Corporation, a Delaware corporation, with principal offices in San Francisco, California, to make a review of the Report of the State Engineer entitled, "Program for Financing and Constructing the Feather River Project as the Initial Unit of the California Water Plan," dated February 1955. This agreement, among other things, embraced a study of the engineering, fiscal, and economic feasibility of said proposed Feather River Project, together with the inherent relationship thereto of the Biemond Plan. The report, prepared under and by virtue of the above agreement, was delivered to the Joint Committee on Water Problems by Bechtel Corporation on the thirty-first day of December, 1955.

In accordance with the terms and provisions of said Senate Concurrent Resolution No. 42, Resolutions Chapter 253, Statutes of 1955, and pursuant to and under authority of the provisions of Joint Rule No. 37, your committee respectfully submits as its Eighth Partial Report the "Report on the Engineering, Economic and Financial Aspects of the Feather River Project to the Joint Committee on Water Problems, California State Legislature, Bechtel Corporation, San Francisco, December 31, 1955."

J. HOWARD WILLIAMS
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PAULINE L. DAVIS
JACK SCHRADE
JOHN J. MCFALL

REPORT

ON THE

ENGINEERING, ECONOMIC AND FINANCIAL ASPECTS

OF

THE FEATHER RIVER PROJECT

TO THE

JOINT COMMITTEE ON WATER PROBLEMS

CALIFORNIA STATE LEGISLATURE

BECHTEL CORPORATION

SAN FRANCISCO

DECEMBER 31, 1955

BECHTEL CORPORATION ENGINEERS – CONSTRUCTORS
TWO TWENTY BUSH STREET · · · SAN FRANCISCO 4, CALIFORNIA

December 31, 1955

HONORABLE HOWARD J. WILLIAMS
Chairman, Joint Committee on Water Problems
California State Legislature, Sacramento, California

DEAR SENATOR WILLIAMS: There is submitted herewith our report on the "Engineering, Economic and Financial Aspects of the Feather River Project" which covers our review of the State Engineer's report, "Program for Financing and Constructing the Feather River Project as the Initial Unit of the California Water Plan." This report is furnished pursuant to the terms of the contract between the Joint Committee on Water Problems and Bechtel Corporation entered into the nineteenth day of August, 1955.

Your attention is particularly invited to the principal conclusions and recommendations immediately following the introduction of this report. These findings show that:

1. There will be a water demand equal to or possibly greater than that proposed in the report.
2. The project is feasible from an engineering standpoint; however, we have recommended that consideration be given to certain modifications of design, operation and terminus.
3. The State's estimates of cost are reasonable; however, our estimates are approximately 3 percent to 9 percent higher for the various routes reviewed.
4. Adequate water is available for this project after allocation of ultimate requirements for upstream users.
5. It is feasible to finance the Feather River Project with general obligation bonds of the State, and the financial requirements of the project appear to be manageable in relation to probable population, income and wealth of the State.

It has been a privilege to participate in these considerations of a subject so vital to the future of the State of California and all of its people. It is our sincere hope that this report will provide your committee and the Legislature with the basic information desired.

Very truly yours,

BECHTEL CORPORATION
J. R. KIELY, Vice President

AUTHORIZATION

This report has been prepared and is submitted pursuant to Senate Concurrent Resolution No. 42, adopted in the Senate April 28, 1955, and in the Assembly June 8, 1955, which reads as follows:

WHEREAS, The Legislature by Chapter 1441, Statutes of 1951, authorized construction of the Feather River Project by the State of California and subsequently appropriated a total of two million two hundred twenty-seven thousand fifty-six dollars ($2,227,056) for the necessary studies, investigations, and surveys and preparation of plans and specifications for the project; and

WHEREAS, There is a recognized need to conserve and develop existing sources of water supply if future domestic, agricultural, and industrial water requirements in the State are to be met; and

WHEREAS, The Water Project Authority, on February 18, 1955, transmitted to the Legislature without comment a report prepared by the State Engineer entitled "Program for Financing and Constructing the Feather River Project as the Initial Unit of the California Water Plan"; and

WHEREAS, The report of the State Engineer concluded that the project is feasible under state financing through the issuance and sale of general obligation bonds of the State secured by water and power revenue and contributions from the General Fund of the State, and recommended immediate action to initiate construction of the project; and

WHEREAS, It is desirable that the Legislature have the benefit of an independent evaluation of the proposal prior to undertaking construction of the project, the cost of which is estimated at approximately one billion five hundred million dollars ($1,500,000,000); and

WHEREAS, The extensive period of time which will necessarily be required to complete the Feather River Project emphasizes the desirability of early implementation of the plan; and

WHEREAS, It is possible to secure a preliminary report prior to the adjournment of the 1955 Session of the Legislature containing general conclusions by independent, competent engineers as to the engineering and economic feasibility of the proposed project, to be followed by a full report to be rendered by December 31, 1955, on engineering, economic and financial aspects of the project, including the inherent relationship of the Feather River Project with the studies recently made by the Board of Consulting Engineers and the State Division of Water Resources on the Biemond Plan and the salt water barriers; and

WHEREAS, The Joint Committee on Water Problems would provide the most suitable means to arrange for an immediate contract with consultants to make a review of the report of the State Engineer and to make available to the Legislature the views of qualified engineering and fiscal personnel not connected with the State of California concerning the proposed Feather River Project; now, therefore, be it

Resolved by the Senate of the State of California, the Assembly thereof concurring, That in addition to any money heretofore made available to it, the sum of two hundred fifty thousand dollars ($250,000) or so much thereof as may be necessary is hereby appropriated from the Contingent Funds of the Senate and of the Assembly for the payment of any and all obligations incurred by the Joint Committee on Water Problems or its members pursuant to and under authority of this resolution and the provisions of Joint Rule No. 37 to be expended equally from the Contingent Funds of the Senate and of the Assembly for the purpose of such a study; and be it further

Resolved, That this resolution shall not be construed as affecting any federal development of the San Luis Reservoir, and be it further

Resolved, That the final report of said consultants shall be made to the Joint Committee on Water Problems or any successor to that committee, or if there be none, then to the Legislature at its first session following December 31, 1955.

The Bechtel Corporation was retained for the review survey contemplated by the above Resolution, through a contract executed with the Joint Committee on Water Problems, under date of August 19, 1955.

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CONSULTANTS

In reviewing the report of the State Engineer the services of the following consultants and consulting organizations were employed.

Consultants

A. H. Ayres	Cost Estimates and Construction Schedules
J. S. Connell	Upper Feather River Area Water Problems
Dean K. Fuhriman	Hydrology
John J. Hammond	Oroville Dam Design
Sidney T. Harding	Water Economics and Demands
Carl A. Heinze	Project Operation and Maintenance
Julian Hinds	Over-all Project Engineering and Economics
Walter L. Huber	Over-all Project Engineering and Economics
A. Kempkey	Water Economics and Demands
A. A. Mathews	Oroville Dam Cost Estimate and Schedule
H. R. McBirney	Aqueduct Design and Operation
Roger Rhoades	Project Geology

Other Consultant Service

American Right of Way and Appraisal Contractors	Rights of Way, Estimated Acquisition Costs
Tudor Engineering Co.	Relocation of Facilities in Oroville Reservoir
Stanford Research Institute	Water Economics and Demands
Blyth and Co. Stone and Youngberg Heller Bruce & Co.	Financial Analysis

ACKNOWLEDGMENTS

Acknowledgment is made of the excellent cooperation and assistance received from Members of the Legislature, the staff of the Offices of the Legislative Auditor and Legislative Counsel, and all personnel concerned of the State Division of Water Resources. Sincere appreciation is also due personnel of the Sacramento District, U. S. Army Corps of Engineers and Regional Office, U. S. Bureau of Reclamation. In the various areas throughout the State that would be affected by the Feather River Project, either directly or even indirectly, our own personnel and those of our consultants received excellent cooperation and assistance from agencies, companies and individuals too numerous to mention by name. This sincere desire on the part of all to contribute their time and information is truly indicative of the widespread realization of the importance of this matter to the people of the State of California.

CHAPTER I

SUMMARY AND RECOMMENDATIONS

INTRODUCTION

The rapid growth of population and the expanding economy of the State of California require the orderly comprehensive development and conservation of the State's natural resources, of which water suitable for domestic, irrigation and industrial use is one of the most vital.

It appears appropriate that the State of California should accept this urgent and complex problem of water as primarily a State problem. A program for such water developments must comprise projects that are integrated parts of an over-all water plan adopted and approved by the people of the State through their representation by the Legislature, and the projects proposed must be within the limits of accepted economics, engineering and financing.

The proposed Feather River Project covered in this review would be a part of this over-all development, and our report considers only its engineering, economic and financial aspects. This report does not propose, however, to offer a solution to the well recognized and expressed conflicts of interest arising from the provisions of current Water Code, and more particularly the "Counties of Origin" and "Watershed Protection" statutes thereof, as they apply or may be interpreted to apply to the diversions and allocations of waters essential to the operation of the proposed project. Active and informed interests, represented by members and committees of the Legislature, officials of the state executive departments, and the legal representatives of affected bodies, both public and private, have been and are seeking an equitable and acceptable solution to these problems. Our review and conclusions drawn thereon are predicated upon the assumption that legislative and/or judicial solutions will be effected that will permit the operation of the Feather River Project as planned.

CONCLUSIONS

Economic Feasibility

A comprehensive and orderly development of the State of California's water resources is essential, and the existing and incipient deficiencies in several areas require settlement of sectional, policy, and legal differences hampering or preventing coordinated action to initiate such developments for the common good.

An urgent requirement now exists for supplemental water supplies, adequate in quantity and satisfactory in quality, to augment present supplies of domestic and irrigation water in the Western San Joaquin Valley. Demands for similar supplemental water supplies will exist in the several other service areas proposed for service by the Feather River Project. A market will therefore be available for all the water the project will develop and deliver to those respective areas at the times and in the amounts indicated in our report. The Feather River Project is a logical component of an essential over-all water development plan of the State's water resources to serve those areas.

Bechtel agrees with the State Engineer's conclusion that the proposed water supplies are satisfactory in quality and are adequate in quantity to meet the Feather River Project demands as scheduled.

On the basis of water availability in the Sacramento-San Joaquin Delta, and apart from consideration of a recognized requirement for flood control below the dam site, completion of Oroville Dam can be delayed until such time that water delivery demands of the Feather River Project reach a total of approximately 2,900,000 acre-feet annually. It is indicated, however, that resultant reduction in pumping costs will justify the completion of Oroville facilities when total project deliveries reach 2,500,000 acre-feet annually. These conclusions are based on the assumption that maximum utilization will be made of the San Luis Reservoir and that there will be no unforeseen impairment of present inflow into the Delta.

Bechtel's estimates of total construction costs for the High Line Route 1, of the State Report were found to be approximately 8 percent higher than those developed by the State Engineer's Report. Bechtel's cost estimates for the other six routes were also higher than the State Engineer's by percentages ranging from about 3.5 percent to 8.4 percent. These variations are within the limits which may be expected in separately prepared estimates based upon the preliminary information available.

The State Report estimates of costs and our review estimates are similarly based on present day costs. Actual final project costs will depend on economic conditions prevailing at time of construction. It is also recognized that the value of water at any future time will be influenced by the same economic conditions.

Under present conditions it is our opinion that the respective markets could meet the following canal

side prices for project water deliveries and that water can be supplied within these price ranges based on present construction costs with reasonable contributions from general funds.

(1) For irrigation in the San Joaquin Valley in the general range of $7 to $9 per acre-foot.

(2) For urban demand in the South Coastal Area at $25 and even up to $45 per acre-foot.

(3) For urban demand in the Alameda-Santa Clara-San Benito Area prices representative of the costs of such delivery in the general range of $17.50 to $22.50 per acre-foot.

The basic power scheme proposed by the State Engineer's Report is a feasible plan for handling the electric power requirements and hydro-electric generation of the Feather River Project.

Planned project water diversions and service deliveries, which are essential to the project's economical and financial feasibility, cannot be realized pending completion of the legislative and possible judicial action required for clarification and settlement of the respective origin and recipient rights to such waters.

Engineering Feasibility

Engineering concepts as proposed by the State Engineer are considered sound with respect to the scope of the Feather River Project.

Preliminary designs of the project, with certain exceptions, as proposed for construction by the State Engineer are in accord with good engineering practices and controlling project factors. Suggested design modifications based upon our review should contribute to the project's engineering and economic feasibility. It is reasonable to believe that the further geological investigations and comprehensive subsurface exploration program and the appropriate surveys essential to final design will give final confirmation to the engineering feasibility of the project.

Financial Feasibility

Estimated capital costs of the proposed Feather River Project are such as to require the issuance of bonds. The issuance of State of California general obligation bonds, to which net revenues of the project are specifically pledged, is recommended as being the most economical and practical means of financing. It is estimated that the bonds should be salable at an average interest cost of 2.7 percent during the approximate 30-year construction period.

The financial requirements of the project appear to be manageable in relation to probable population, income and wealth of the State, and therefore it is our considered judgment that, subject to the conditions outlined herein, it is feasible to finance the Feather River Project with general obligation bonds of the State.

RECOMMENDATIONS

It is recommended that:

1. The Legislature consider early enactment of legislation which will.
   a. Clarify existing statutes and codes as they apply to the diversions and allocations of waters essential to the planned operation of the proposed Feather River Project.
   b. Make appropriate delegation of authority to existing agencies, or create any new agency or agencies which the Legislature may determine as required to effectively finance, construct and operate the project.
   c. Authorize and provide the appropriations required for the early initiation of action to acquire property and rights-of-way interests necessary for Oroville Dam and Reservoir and for San Luis Dam and Reservoir, with their appurtenant facilities, exclusive of aqueducts.
   d. Define the ultimate project scope in general accord with those major areas to be served and the total project supplemental water delivery concepts proposed by this Feather River Project Report review.
   e. Appropriate funds for earliest start of work on the development of engineering design for the project, including comprehensive subsurface investigations and topographic surveys.
   f. Submit to the electorate a proposal to authorize issuance of adequate bonds to finance construction of the project in a step construction program. It is further recommended that the use of funds to be derived from such progressive bond sales be conditioned on substantial commitments to purchase project water by the several areas to be served before the active construction of these portions of the project providing for service to each area may be undertaken.

2. Federal participation in the cost of Oroville Dam and Reservoir be actively developed by the appropriate state executive agency or agencies in view of the flood control benefits which will be derived therefrom. Such federal participation could contribute to the justification of earlier construction of Oroville Dam.

3. The agency responsible for the development of the project give consideration to:

   a. The recommended project modifications of design of major features, such as San Luis Dam and Afterbay Dam No. 2 at Oroville, and proj-

ect operation incorporated in this report in further project development studies, with particular reference to the merits of incorporating those desirable elements of the Biemond Plan currently under active State Engineer study.

b. Aqueduct studies directed toward stage development of the High Line route via Castaic Creek power development and terminating in San Fernando Valley. This aqueduct route is described in Chapter III as Bechtel Alternate Route 10. On the basis of Bechtel's water demand studies, the design and operation of Route 10 should incorporate Bechtel's operating modifications and forecast of water demands as described in Chapter III under Modification 10A. Under this plant the southern part of the South Coastal Basin then could be served more economically from the Colorado River Aqueduct through the exchange of waters, than by overlapping of existing distribution systems.

SUMMARY DESCRIPTION OF PROJECT

Construction of the Feather River Project by the State of California, acting through the Water Project Authority, was authorized by the 1951 Legislature. A total of $2,227,056 was appropriated by the 1952-3-4 Legislatures for studies, investigations and surveys. No money has been appropriated to date for construction.

The Feather River Project as described in the State Engineer's Report is very briefly described again herein for the purposes of reference and identification of routes.

The Feather River Project's proposed purposes are: flood control and irrigation in the Sacramento Valley; electric power generation; and furnishing Feather River water for firming surplus waters existing in the Sacramento-San Joaquin Delta, in most years, to provide a water supply to areas of water deficiency on the west side of the San Joaquin Valley in Fresno, Kings and Kern Counties, to South San Francisco Bay area in Alameda, Santa Clara and San Benito Counties, and to Southern California.

The basic plan (High Line Route) reported upon by the State Engineer is composed of the following project features:

Oroville Reservoir, Dams, and Power Plant

The Oroville Reservoir, Dams and Power Plant, consists of a concrete gravity main dam 730 feet high above streambed, 6,780 feet long including the spillway section, with a base thickness of 680 feet at streambed, with a concrete volume of about 14,000,000 cubic yards and requiring excavation of about 4,000,000 cubic yards (the estimated concrete yardage for the gravity dam section would be about 3,500,000 cubic yards more than the amount used for Grand Coulee Dam and more than twice that placed in Shasta Dam, and the maximum height above foundation bedrock would be about 20 feet greater than that of Hoover Dam and 140 feet greater than Shasta Dam), creating a reservoir of about 3,500,000 acre-feet gross capacity; two afterbay dams for re-regulation; and a power plant at the downstream toe of the main dam of 440,000 kw. installed capacity. Estimated cost as contained in the State's Report is $418,661,000, including about 10 percent each for contingencies and for engineering and administration.

High Line Plan

The High Line plan, hereinafter referred to as Route 1, for the Feather River Project Aqueduct, starts at a Delta Cross Channel, and would convey water flowing from the Sacramento River to the Intake Pumping Plant where it would be lifted 230 feet to the aqueduct, thence by concrete lined canal nearly paralleling the Delta-Mendota Canal to San Luis Creek, about 12 miles west of Los Banos, which would be the location of San Luis Dam and Reservoir to be built for storage and regulation as a 68,000,000 cubic yard earth-fill dam, 18,700 feet long by 310 feet high, with an ultimate reservoir capacity of 2,100,000 acre-feet. From the San Luis Reservoir the aqueduct would follow the west side of San Joaquin Valley to Wheeler Ridge, traversing the Tehachapi Mountains, and on south to Horse Thief Canyon behind Barrett Dam in San Diego County, through use of canals, siphons and tunnels, including two consecutive tunnels of 10½ miles length through the Tehachapis. There would also be a 108-mile branch aqueduct, served by pumping from the main canal, that would provide water to Alameda, Santa Clara and San Benito Counties. Seven pumping plants along the 585-mile main conduit are contemplated, including one to lift 5,000 cfs. about 1,900 feet at Pastoria Creek to the Tehachapi tunnels. This aqueduct system is estimated in the state report to cost $1,174,247,000, including about 15 percent for contingencies and 10 percent for engineering and administration.

In this High Line plan the State Engineer anticipated that delivery of the full supplies of water of 3,880,000 acre-feet per year by the Feather River Aqueduct would not occur until 29 years after completion of the Oroville Power Plant in 1963. Water revenues are based on a rate of $45 per acre-foot for 1,800,000 acre-feet in Southern California; $22.50 per acre-foot for 240,000 acre-feet in Alameda, Santa Clara and San Benito Counties; $9 per acre-foot for 350,000 acre-feet in southern Kern County area; and $8 per acre-foot for 1,490,000 acre-feet in Fresno, Kings and northern Kern Counties.

The total High Line Project, Route 1, was estimated by the State Engineer to cost $1,592,908,000 which

includes the cost of Oroville Reservoir, Dams and Power Plant.

The report of the State Engineer also presents two possible modifications of the High Line plan, which do not deliver water to the same areas as the High Line, one with the aqueduct terminating near San Bernardino, hereinafter referred to as Route 2, and the other terminating near Castaic, 10 miles south of Grapevine, titled Route 3 in this report. Two other possible routes, with modifications to each, to bring water to the South Coastal Area, were also reported upon by the State Engineer, one by way of the so-called Coastal Line and the other by the Long Tunnel Line. These two routes or their modification do not provide the same water delivery to the same areas as the basic proposed High Line Route. All of these routes and cost estimates thereof include the Oroville Reservoir, Dams and Power Plant.

Route 2 would terminate the main aqueduct at a Cedar Springs Forebay, on the Mojave River, about 12 miles north of San Bernardino, and would include a 440,000-kw. ultimate capacity power plant at Devil Canyon near San Bernardino. The State Engineer's estimated project cost was $1,491,147,000.

Route 3 would terminate the main conduit at a Quail Lake Forebay, about 18 miles northwest of Castaic, and waters would be released through power drops and two plants of a total 516,000-kw. ultimate capacity to the Castaic Creek Reservoir near Castaic. The State Engineer's total estimated project cost was $1,395,522,000.

Coastal Line

The Coastal Line would begin at Mile 340, near Devils Den east of Paso Robles, on the main aqueduct in San Joaquin Valley, traverse the mountain range through Polonio Pass, crossing the Salinas River near Santa Margarita, passing about seven miles east of San Luis Obispo, six miles southeast of Santa Maria, on through Santa Barbara County and along the mountains north of Carpinteria into Ventura County and easterly between Saugus and Newhall, serving this southern coastal area by pumping lifts, 70 miles of tunnels, 205 miles of canals and 24 miles of siphons to Castaic Creek Reservoir. A reduced capacity extension of the main canal would still be provided to Wheeler Ridge. The State Engineer's estimated cost was $1,549,988,000. This route will be referred to as Route 4.

If the Coastal Line was not terminated in Castaic Creek Reservoir, but extended another 117 miles to the San Jacinto Tunnel West Portal of the Colorado River Aqueduct, the State Engineer's total estimated cost was $1,837,567,000. This extended coastal route will be referred to as Route 5.

Long Tunnel Line

The Long Tunnel Line would be the same as the High Line Route 1 to the Pastoria Creek Pumping Station south of Wheeler Ridge, near Grapevine, however, from that point it would go through several short tunnels and then a 26.7-mile long tunnel through the Tehachapi Mountains to terminate in the Castaic Creek Reservoir. The State Engineer's estimated cost was $1,381,841,000. This route will be referred to as Route 6.

If the Long Tunnel Line were not terminated at Castaic Creek Reservoir, but extended to the San Jacinto Tunnel West Portal of the Colorado River Aqueduct, its total length from Pastoria Creek would be about 157 miles, of which 38 miles would be canal, 95 miles of tunnel, 5 miles of siphon, and 19 miles of covered conduit. The State Engineer's total estimated cost was $1,638,252,000. This extended Long Tunnel Route will be referred to as Route 7.

Bechtel Modifications

In addition to the routes covered in the State's Report, this review will cover four possible modifications of those routes for water service in the South Coastal Basin considered by Bechtel. These routes are also briefly described here and identified by route numbers for facility of reference throughout this report.

An aqueduct route using the High Line Route from the Delta to Devils Den, and thence via the Coastal Line Route to Castaic Creek Reservoir and from Castaic Creek Reservoir across the upper Santa Clara Valley and through Newhall Gap to a terminal reservoir in the western San Fernando Valley near Granada Hills. A lateral aqueduct is included for the area between Devils Den and Wheeler Ridge. This route will be referred to as Route 8.

An aqueduct route using the High Line Route from the Delta to Pastoria Creek, and thence via the Long Tunnel Line to Elizabeth Lake Canyon and Castaic Creek Reservoir, and then from Castaic Creek Reservoir across the upper Santa Clara Valley and through Newhall Gap to a terminal reservoir in the western San Fernando Valley near Granada Hills. This route will be referred to as Route 9.

An aqueduct route using the High Line Route from the Delta to Quail Lake Forebay, and thence via Castaic Creek Power Development into Castaic Creek Reservoir and thence across the upper Santa Clara Valley and through Newhall Gap to a terminal reservoir in the western San Fernando Valley near Granada Hills. This route will be referred to as Route 10.

An aqueduct route using the High Line from the Delta to about Mile 500 on that route in Antelope Valley, thence southerly via Elizabeth Lake Reservoir, Cherry Canyon, Middle Bouquet Canyon and Haskell Canyon Reservoirs to the east end of the Santa Clara

Valley and through Newhall Gap to a terminal reservoir in western San Fernando Valley near Granada Hills. This route will be referred to as Route 11.

METHOD OF REVIEW

On August 19, 1955, Bechtel was notified to proceed with the review of the State Engineer's report and to submit its findings to the Joint Committee on Water Problems by December 31, 1955. This limited time required that practically all phases of the review start and proceed concurrently. Consequently, studies such as engineering and design feasibility that normally would await completion of geological and hydrological examinations and water demand studies, were initiated immediately. Similarly, checking of construction cost estimates, construction schedules, right of way acquisition costs, relocation costs, power studies and economic feasibility studies also proceeded immediately. The review of the financing prospects was deferred until all features had received a check verification or Bechtel's differences had been developed for the State Engineer's basic High Line program.

Within a few days following selection of Bechtel Corporation and award of the contract for the review of the report, initial meetings of management, key staff and selected consultants outlined the division of work, scope of the project, and basic guide lines for conduct of the review. These meetings were immediately followed by visits of the principals, accompanied by representatives of the State Engineer's Office, to the Oroville Dam and Reservoir site, and by aerial examination of the aqueduct routes and sites for related appurtenances for a visual appreciation and grasp of the scope and magnitude of the proposed project. Resident liaison was established with the State Engineer's Office within a few days of the contract award by locating a Bechtel representative in that office. State Engineer personnel were fully cooperative in making available the mass of back-up detail from their files required for the review of the report.

The engineering review and studies were conducted with the consultation of John J. Hammond on the Oroville Dam; H. R. McBirney on the aqueduct proper; Roger Rhoades on the project geology; D. K. Fuhriman on project hydrology; J. S. Connell on Upper Feather River Area problems; Carl Heinze on project operation and maintenance; and the Tudor Engineering Company on relocation of facilities in Oroville Reservoir. The office studies were supplemented by field trips required to adequately assess the state data and to gather additional information or develop possible alternate considerations.

The cost estimates of the project were developed by Bechtel with the consultation of A. H. Ayers and A. A. Mathews on construction costs and construction schedules; the Tudor Engineering Company for estimated costs of relocation of facilities in Oroville Reservoir; Carl Heinze on project operation, maintenance and replacement costs; and the American Right of Way and Appraisal Company on estimated costs for acquisition of appropriate rights of way interests including severance damages.

Stanford Research Institute assisted in the economic evaluation and water demand studies. As pointed out in more detail in its report appended hereto, basic information relating to area water demands, rates of buildup of such demands, and marketability of the water at the canal-side rates indicated in the State Report had not been developed by the State Engineer in detailed studies. Consequently, considerable original work had to be undertaken to develop more conclusive and directly related information by studies of land-use, population forecasts, farm-income and ability to pay, water application rates and resultant demands, current irrigation pumping costs, ground water overdrafts and other pertinent aspects and by numerous field trips to develop information from representative water distributors and users. S. T. Harding and A. Kempkey consulted with Bechtel in those aspects of the economic feasibility related to water demand as developed by the necessarily brief original studies of Stanford Research Institute.

The financial studies were basically developed by Blyth and Company; Heller Bruce Company, and Stone and Youngberg Company utilizing information developed and supplied by Bechtel as to project costs and revenues. These studies were directed towards either verifying the financial feasibility of the financial programs as presented by the State Engineer's report or to develop a better financial program for the project.

In the over-all evaluation of the Feather River Project, Julian Hinds and Walter Huber consulted extensively throughout the development of all phases of the engineering and economic review as well as in the formulation of the summary conclusions and recommendations concerning the complete project.

RELATION TO OTHER WATER PROJECTS

California Water Plan

As stated in the report of the State Engineer the Feather River Project is the initial unit of the California Water Plan. The relationship of the Feather River Project to the California Water Plan cannot at present be defined because the Master Plan has not been completed. The Division of Water Resources proposes to publish a Bulletin No. 3, "Plan for Development of Water Resources of California" upon completion of current studies. This bulletin should fully

describe how the Feather River Project fits into this state-wide plan.

It is known, however, that the State's proposed Feather River Project is not planned or designed to supply the ultimate requirement of the areas which it proposes to serve, nor is it planned and designed to serve all areas of California that have or anticipate early water deficiencies, such as Contra Costa County. It then must be anticipated that the additional water to meet ultimate requirements of the Feather River Project areas, as well as requirements of other water deficient areas adjacent thereto, will be delivered through a future and perhaps parallel aqueduct with some of the water being supplied from watersheds in Northern California other than the Feather River. This would constitute another stage of development in the comprehensive California Water Plan.

The proposed Feather River Project is designed to deliver to its service areas a maximum of 3,880,000 acre-feet of water annually, which, as stated previously, does not propose to meet the ultimate requirements of these areas.

Based on the State's estimate of water demands and absorption period, the areas to be served will require additional water over and above those Feather River Project deliveries by the following years, which in each case is within 15 years after initial deliveries to the respective areas:

Fresno, Kings and northern Kern Counties Area	1972
Southern Kern County Area	1972
Alameda, Santa Clara and San Benito Counties Area	1979
Southern California	1991

Any decrease in the absorption period would reduce the number of years for start of work on a supplemental water supply system. Bechtel's preliminary studies of water use rates in the northern portion of the San Joaquin Valley indicate that a shorter absorption period is a possibility. It is, therefore, recommended that these absorption periods be carefully studied during the final design. If it is determined that there is need for a supplemental water system in less than 10 years, consideration should be given to building the aqueduct of a capacity adequate to satisfy the service areas for not less than 15 years. This determination, however, must be made within the concepts of the over-all California Water Plan program for these affected areas, as additional regulated sources of supplemental water supplies to the Delta would also be required.

Biemond Plan

The "Biemond Plan" is essentially a plan for the control of salinity in the Delta, however, other elements considered in the plan include water supply, drainage, and flood control.

Salinity control is provided in the Biemond Plan by the construction of a separate fresh water channel across the Delta and weirs across the Sacramento River and Steamboat Slough near Junction Point. The control structures will effect a separation of fresh and saline waters. Rising ground water and return irrigation water which are known to be of poor quality will be carried away through separate channels.

Flood control in the Delta will be improved by confining the channels of the rivers in substantial main line levees. Navigation locks are provided to accommodate river traffic.

Fresh water from the Sacramento River will be diverted near Isleton and conveyed across the Delta in an independent channel and through a siphon under the San Joaquin River to the intake pumping plants near Tracy for export to points to the south.

The Feather River Project as planned by the State includes the construction of an unconfined Delta Cross Channel to facilitate the supply of additional water to the project intake. The State estimates that this channel will be required by the time the Feather River Project water requirements reach 1,500,000 acre-feet per year.

A confined Delta Cross Channel, whether constructed separately or as part of the Biemond Plan, to separate the higher quality water of the Sacramento River from drainage, return flows, and the deteriorated low flow waters of the San Joaquin River is more desirable, not only for Feather River Project waters, but to improve waters for existing irrigation projects taking water from the Delta.

San Luis Unit of the Central Valley Project

The relative place of the San Luis Unit in the proposed California Water Plan and particularly its relation to the Feather River Project raises a question as to whether the "unit," as proposed by the Bureau of Reclamation, fits in physically and economically with the State's plan.

The San Luis Unit of the Central Valley Project, as proposed by the Bureau of Reclamation, is a plan to provide 1,250,000 acre-feet of supplemental water for irrigation to approximately 440,000 acres of land on the west side of the San Joaquin Valley and also to provide additional municipal water supplies to a few urban areas. The water supplied would supplement and improve existing supplies from ground water sources which are being seriously overdrawn.

For service to the San Luis area, the state and bureau plans are basically similar, except that the Feather River Project as planned will furnish supplemental water to additional areas in the San Joaquin Valley and to Southern California. Both plans pro-

pose pumping diversion from the Sacramento-San Joaquin Delta, use of the San Luis Reservoir and a high-level canal from that reservoir throughout their respective service areas.

The Federal San Luis Unit Project proposes to use the excess capacity of the Tracy pumping plant and the Delta-Mendota Canal for diversion of its water supply to the proposed San Luis Reservoir, requiring a storage reservoir at the San Luis site having a capacity of 1,000,000 acre-feet. The Feather River Project would take about 3,800,000 acre-feet of water through a separate pumping plant and conduit to the San Luis Reservoir Forebay, with San Luis Reservoir built to an ultimate capacity of 2,100,000 acre-feet.

Some immediate solution of the problems of the western San Joaquin Valley is essential because of the imminent failure of ground water supplies. The State has recommended the Feather River Project for this purpose, coupled with a more extensive irrigation coverage of the valley and the requirements of Southern California.

Trinity River Division—Central Valley Project

The Trinity River Division proposed by the U. S. Bureau of Reclamation is a plan whereby excess waters from the Trinity River and Clear Creek are diverted into the Sacramento River through the Keswick Reservoir.

The plan consists of the Trinity Dam, Lewiston Diversion Dam, Tower House Tunnel Diversion Dam and the Matheson Tunnel, with potential power developments at Trinity, Lewiston, Tower House, and Matheson Power Plants and all necessary transmission lines.

The Bureau of Reclamation report states that upon completion of the Trinity River Project approximately 525,000 acre-feet of additional water would be made available annually for Central Valley Projects such as the San Luis Unit. It would follow that these waters could then be made available in the Delta for the Feather River Project if the San Luis Unit is not constructed.

As the bureau's releases from Trinity for power generation may well be at times of maximum flow in the Delta area, Bechtel has been unable to conclude that such supplemental waters may be completely credited to Feather River Project demands. The quantity of additional water which will be usable by the Feather River Project upon completion of the Trinity Project therefore must be determined in conjunction with the Bureau of Reclamation.

The Trinity Plan proposes an installed hydroelectric power capacity of 233,000 kw. and an estimated power output of 1,067,000,000 kilowatt hours per year. Other benefits of the Trinity Plan, such as flood control, fisheries, and recreation are provided but do not directly affect the Feather River Project.

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES

FEATHER RIVER PROJECT

CHAPTER II

WATER STUDIES

INTRODUCTION

To determine the amount of water available for delivery to the service areas of the proposed Feather River Project, it is necessary to study the available water at two principal locations: (1) at Oroville Dam site on the Feather River, and (2) at the Sacramento-San Joaquin Delta. At each location the available water can be computed from the natural flow of the upstream river system as modified by water reservations, water exports, water storage changes, and water consumptively used.

For the Feather River upstream from Oroville Dam site, the total effect of the modifying factors upon the natural flow of the river system is relatively small; the net average annual depletion of stream flow in this area is, and will be less than 10 percent of the natural flow, even in very dry years. However, in the case of water available at the Delta, the natural flows are greatly depleted in quantity and modified in quality and distribution. This is due to the tremendously large and complicated imports, exports, storage changes, and consumptive uses on all of the tributary streams of the Sacramento-San Joaquin River system upstream from the point of diversion.

In order to evaluate the effectiveness of Oroville Dam in providing water supply benefits, it is necessary to study the relationships between water supply and water demand under two sets of conditions: (1) assuming the dam is to be constructed, and (2) assuming the construction of the dam is to be postponed. This section of the report will discuss the methods and procedures used by Bechtel in evaluating the benefits to be derived from Oroville Dam and is related to pages 13 through 23 of the State Report.

For the most part, the State has used standard hydrologic methods and procedures in studying the problem of water supply. The studies by the State are based largely on reliable stream flow data, reservoir operation data, irrigation records, and consumptive use experiments. These investigations were made in three steps, as follows:

Determination of monthly "present impaired" flows of Feather River at Oroville Dam site. These flows would be the inflows to Oroville Reservoir.

Determination of the regulated, monthly outflows from Oroville Reservoir. This was based on the stream flows as determined above and on Feather River Project demands.

Determination of monthly quantities of water in the Delta available for Feather River Project export. This was based on flows determined in the paragraph above and on contributions from all other streams tributary to the Delta, assuming coordinated operation of existing Central Valley Project units.

SUMMARY CONCLUSIONS

The water studies for the Feather River Project review were divided into two categories: water supply and water quality. Following are the principal conclusions from these studies.

The water supplies of the Feather River Project as proposed by the State are more than adequate to meet scheduled project demands.

The water supply benefit creditable to Oroville Dam for firm deliveries of 730,000 acre-feet of water to the Feather River Service Area is about 55,000 acre-feet annually.

Routing studies by Bechtel indicate that there will be sufficient water in the Sacramento-San Joaquin Delta to supply Feather River Project demands, without additional regulation facilities on Feather River, until there is a requirement for delivery of 2,900,000 acre-feet annually for use south of the Delta.

These studies assumed that maximum utilization would be made of the full capacity of 2,100,000 acre-feet of storage in San Luis Reservoir, and that the rate of development of areas which impair the inflow to the Delta would not exceed the estimated demands shown herein. It was also assumed that water availability is the controlling factor.

After completion of the first stage of the possible two-stage construction of San Luis Dam, the reservoir will have a usable capacity of 1,000,000 acre-feet. If maximum utilization is made of this capacity, and all other assumptions remain as determined above, the completion of Oroville Dam can be postponed until the water demand of the Feather River Project reaches approximately 1,700,000 acre-feet annually for use south of the Delta.

The Bechtel studies show that in some of the low flow months of certain years, there will be theoretical deficiencies in deliveries to the Alameda-Santa Clara-San Benito Aqueduct, because these deliveries must be made upstream from San Luis Reservoir. From a practical point of view, these theoretical deficiencies could be overcome by small temporary decreases in salinity control releases, or by additional coordination with local surface or under-

ground storage. At those times those areas may be increasingly dependent on local supplies.

Major factors tending to make these water supply determinations conservative are as follows:

The 1927-34 period represents the most severe dry period in the past 100 years, and the probability of a more severe dry period occurring in the next 30 years is therefore not very great.

No credit was taken for additional water available from the Trinity Division Project, when and if it is completed.

A 4,500-cfs. minimum release for salinity control was used, instead of 3,300 cfs. as used at present in the operation of the Central Valley Project.

The impaired flows into the Delta used by the State included subtraction of water for ultimate irrigation diversion to the Sacramento Canals unit and to most of the Folsom unit. These units are not estimated by the bureau to reach a stage of ultimate development until about 1975 to 2000. In addition, no return flows from these units were considered to be available.

Bechtel Corporation recommends that the State consider seeking some financial contribution from the Federal Government for the realistic flood control benefits creditable to Oroville Dam. In order to set such a value, the entire problem of determining flood control benefits creditable to Oroville Dam should be thoroughly reviewed in accordance with present standard flood control procedures. Because the U. S. Army Corps of Engineers has had more experience on flood control problems than any other agency in the United States, it is recommended that the established procedures of the Corps be used.

The flood control operational criteria should be also restudied, including the amount of storage provided and the magnitude of reservoir releases under various conditions. Alternative flood protection should be considered in connection with possible increased power revenues if higher reservoir elevations could be maintained.

The State's evaluation of the quality of Feather River Project water is sound. Additional fish, wildlife, and recreational benefits will accrue when Oroville Dam is constructed. The postponement of that feature would, of course, temporarily leave existing conditions unchanged.

The quality of water at the intake of the Feather River Aqueduct is, and probably will remain, suitable for all uses contemplated in the project.

Construction of separate channels for the Sacramento and San Joaquin River systems would insure good quality water for future uses in and exports from the Delta.

FLOW OF FEATHER RIVER AT OROVILLE DAM SITE

For clarity of presentation of these water studies, four different classifications of stream flow are defined, as follows:

Historical Flow is the flow which passed Oroville Dam site and was measured at the U. S. G. S. gaging station at the site. Historical flow reflects the effects of actual upstream use, regulation, imports, and exports. The records of these particular flows, described by the U. S. G. S. as "excellent," provide the best information available on stream flow which passed the dam site.

Natural Flow is the flow which would have occurred in the past without man-made developments. These flows are computed using historical flows as a base and adding or subtracting the effects of historical upstream use, regulation, imports, and exports.

Present Impaired Flow is the flow which would have occurred in the past under the conditions of present developments upstream. These flows are computed using the natural flows as a base and subtracting or adding the effects of present upstream use, regulation, imports, and exports, and are used as the inflows to the Oroville Reservoir in the project operation study. These flows are also used as the flows available in the Feather River at Oroville for the phases of the Bechtel study which assume postponement of construction of Oroville Dam.

Probable Ultimate Impaired Flow is the flow which would have occurred in the past under conditions of probable ultimate upstream development. These flows are computed using the natural bows as a base and subtracting or adding effects of probable ultimate upstream development, including uses, regulations, imports, and exports.

The base period used in the State's studies was the 31-year period from 1921-1951, inclusive. For this period, the mean annual natural and present impaired flows were about 87 percent of the respective mean annual flows for the longer 50-year period from 1902-1951. Because the mean flows used represent a below average flow period, water supply determinations based thereon are conservative. The effect of including data later than 1951, which were not readily available at the time of the state studies, is negligible. Yearly natural and present impaired flows for the base period are listed in Table 8 of the State Report. Yearly historical and probable ultimate flows, in addition to the above flows, are tabulated on page 187 of the State's Upper Feather River Service Area Report. Specific details of average annual, present and ultimate impairments of the flows of Feather River above Oroville Dam Site are listed on pages 185 and 186 of the same Upper Feather River Service

Area Report. Monthly present impaired flows are shown in Appendix E-1, page 85, of the State Report. The methods and proeedures for computing natural flow and present impaired flow have been ehecked, and the results obtained by the State are believed to be reasonable and within the limits of the probable errors of the data and measurements used.

The methods and procedures for computing probable ultimate impaired flow have been checked and are believed to be sound. The results obtained by the State with regard to impairments in the Feather River Basin above Oroville Dam Site were likewise found to be reasonable. The unit demands for agricultural, industrial, urban, and recreational developments and also the respective quantities of such developments to which the unit demands were applied were found to be on the safe side. However, loeal interests in some areas have questioned the criteria established by the State for truly ultimate conditions. In the foothill regions near Oroville in the Upper Feather River Service Area, it is believed that the figures of the State should be reviewed to see if they represent the ultimate development.

As previously defined, the probable ultimate impaired flow is that flow which would occur under conditions of ultimate development. The problem is to estimate the ultimate agricultural, urban, industrial, recreational, and power development in the area, the water demands thereof, and the depletions and modifications of stream flow resulting therefrom. Any attempt to estimate the degree of technological, economic, and social development at some undefined "ultimate" point, would be subject to error. It is the establishment of the water demands for conditions of ultimate agricultural development that the disagreement noted above exists. These agricultural demands represent the greatest portion of the total ultimate demands.

In determining the total water demand for a given agricultural area, it is neeessary to set forth certain elements of the problem to be evaluated. These elements should inelude the following:

Gross irrigable area is the total area of land meeting minimum physieal requirements for irrigated agriculture. Factors relating to the economics of irrigation development are not considered.

Net irrigable area is the portion of the gross irrigable area which is estimated to be irrigated in any one year. The relationship of net irrigable area to gross irrigable area is determined by making appropriate allowances for necessary rights of way, homes, farm buildings, and necessary agricultural practices such as erop rotation and fallowing.

Consumptive use is the amount of water actually consumed by crops in building plant tissues and through evapo-transpiration.

Consumptive use of applied water. While much of the moisture which falls on the land as rain runs off to streams and rivers or is evaporated before it can be put to beneficial use in crop development, some of the required moisture usually stays in the ground where it can be used. The consumptive use of applied water is equal to the total consumptive use minus the amount of naturally deposited water which is actually used for growing crops.

Farm delivery requirement is the amount of water required at the farm headgate to supply both the farm consumptive uses and the farm distribution system losses.

Water demand of a given area is equal to all of the farm delivery requirements plus the conveyance losses to the farm.

Over-all system efficiency is equal to the consumptive used divided by the water demand.

Based upon field inspection and extensive discussion of the ultimate development problem with the people involved, Bechtel studies indieate that the users in a few of the particular areas in the vicinity of Oroville have unusual water use conditions and that these conditions may not have been fully considered in computing the ultimate development of the areas. Conversely, there is also some indication that the water users have assumed, in their own estimates of water demands, irrigation efficiencies which are too low for conditions of ultimate development. A specific evaluation of particular areas involving reclassification of land, redetermination of consumptive use and irrigation and delivery efficiencies, etc., was considered to be outside the scope and time allowed for this review. Therefore, as previously stated, it is recommended that further study be made of the probable ultimate development in the foothill region of the Upper Feather River Service Area.

In its project study, the State used the present impaired flows of Feather River at Oroville Dam Site as the inflows to Oroville Reservoir. It is likely that the rate of development in the Feather River Basin above Oroville Dam will be slow for some time. Nevertheless, during the amortization period of the project, some increased impairment of flow over present conditions will undoubtedly oecur. The State estimated the probable ultimate impairment above Oroville Dam Site to average about 570,000 acre-feet annually as compared to the present impairment of about 309,000 acre-feet. Sinee the probable ultimate development is not likely to be reaehed by the time of completion of the proposed Feather River Project, the actual impairment of natural flow will probably remain less than 10 pereent of the 50-year mean flow. Even with ultimate impairment upstream from Oroville Dam, the projeet operation would still be able to achieve its established objective. Furthermore, with the con-

struction and operation of dams and reservoirs contemplated on the upstream tributaries under ultimate conditions, the flow at the Oroville site would be modified favorably with regard to project operation. Even though the total quantity of flow would decrease because of increased upstream use, the change in the distribution of flow at Oroville, resulting from upstream releases in low months, would result in a net benefit to the project. Therefore, it is believed that the use of probable ultimate impaired flows or some impaired flows between the present and the ultimate, would not basically change the results obtained by the State.

OROVILLE RESERVOIR

The following paragraphs describe those phases of the studies by the State and by Bechtel which pertain to water supply and flood control operations of Oroville Reservoir. Inflows to the reservoir were the "present impaired flows" for the selected study period, 1921-51, inclusive.

Oroville Reservoir areas and capacities are shown on Table 9 of the State Report and are reproduced below.

AREAS AND CAPACITIES OF OROVILLE RESERVOIR

Reservoir elevation (feet)	*Surface area (acres)*	*Reservoir capacity (acre-feet)*
200	0	0
220	26	200
240	67	1,100
260	115	3,100
280	200	6,300
300	300	11,300
320	445	18,700
340	605	29,200
360	799	43,300
380	995	61,200
400	1,189	83,100
420	1,450	109,500
440	1,705	141,000
460	2,000	178,500
480	2,327	221,700
500	2,685	271,800
520	3,085	329,400
540	3,500	395,300
560	3,927	470,000
580	4,340	552,700
600	4,738	643,300
620	5,250	743,200
640	5,785	853,400
660	6,355	975,100
680	6,970	1,108,300
700	7,618	1,254,100
720	8,260	1,412,600
740	8,950	1,584,600
760	9,675	1,770,700
780	10,450	1,972,000
800	11,220	2,188,600
820	12,050	2,421,200
840	12,900	2,670,800
860	13,780	2,937,700
880	14,600	3,221,600
900	15,450	3,522,800

The State's computations are based on U. S. Bureau of Reclamation topographic maps from aerial surveys with a scale of $1'' = 400'$ and a contour interval of 10 feet. As a check on the state calculations, the reservoir area was measured on U. S. G. S. topographic maps (scale of 1:24,000). The result was found to agree with the areas shown in the State Report within reasonable limits. The calculations for reservoir capacity were also found to be satisfactory. Reservoir evaporation was checked and the effect of net evaporation upon water available from Oroville Reservoir was found to be insignificant.

The State assumed the operation of Oroville Reservoir will supply an annual total amount of 730,000 acre-feet of water for diversion to the Feather River Service Area (between Oroville and Nicolaus) and to supply a variable annual amount for downstream uses and diversions for the Feather River and Central Valley Projects. The scheduled diversions to the Feather River Service Area on a monthly basis are shown on page 16 of the State Report. Water quantities for downstream uses and diversions of the Feather River and Central Valley Projects were computed by the State from a study of the operation of Oroville Reservoir in relation to other sources of inflow into the Sacramento-San Joaquin Delta and are shown on a monthly basis in the State Report in Appendix E-2 and on a yearly basis on page 20 of the same report.

As a check against the State's figure for present diversion requirements of the Feather River Service Area, the records of diversions from the Feather River for the years 1924 through 1953 were examined. These are listed in the Report of Sacramento-San Joaquin Water Supervision, published yearly by the State. A tabulation of those March-October, inclusive, diversions to the nearest 1,000 acre-feet is shown in the following table:

Year	DIVERSIONS FROM MARCH-OCTOBER (acre-feet)	Year	DIVERSIONS FROM MARCH-OCTOBER (acre-feet)
1953	792,000	1938	513,000
1952	727,000	1937	508,000
1951	727,000	1936	479,000
1950	662,000	1935	391,000
1949	716,000	1934	428,000
1948	586,000	1933	478,000
1947	674,000	1932	497,000
1946	745,000	1931	464,000
1945	698,000	1930	446,000
1944	713,000	1929	449,000
1943	624,000	1928	492,000
1942	540,000	1927	528,000
1941	475,000	1926	469,000
1940	474,000	1925	413,000
1939	501,000	1924	355,000

An inspection of the table shows that the actual diversions have increased historically in keeping with the progressive development of the area. During the 10-year period, 1944-53, the diversions varied from 586,000 acre-feet to 792,000 acre-feet, and averaged 704,000 acre-feet. It is concluded, therefore, that the State's estimate of 730,000 acre-feet is representative of present conditions.

The State concludes that Oroville Reservoir will obtain water supply benefits in the Feather River Service Area as follows:

> "Provision of a firm irrigation supply of 730,000 acre-feet per year for use in the Feather River Service Area, with an increase of such supply to 970,000 acre-feet as required, with a consequent decrease in power revenue. The foregoing irrigation supplies compare with the presently available dry year irrigation supply from the Feather River estimated to be about 450,000 acre-feet." (State Report, page 22.)

It is true that these firm water supplies can be achieved with Oroville Dam. However, the historical diversions, even in dry years, have been determined much more by progressive development of the area than by the amount of water flowing in the river. At the present time, the development of the area is nearly as complete as is economically and physically feasible without additional upstream storage. Based on a comparison between the present impaired flow at the Oroville site and the irrigation diversion requirement in the Feather River Service Area, as presented in Appendix E-1 of the State Report, the additional water to provide a firm supply creditable to Oroville Dam averaged about 55,000 acre-feet per year. The supply available for irrigation diversion in the driest year of the 1921-51 study period was 578,000 acre-feet. Only about 150,000 acre-feet of reservoir storage would be required for 730,000 acre-feet of firm annual diversion supply; approximately 300,000 acre-feet of storage being needed to provide 970,000 acre-feet of firm diversion supply.

A review of the operation studies of the State Report indicated that while the stated ultimate project demands can be met by the water supply from Oroville Reservoir supplementing the waters otherwise available in the Sacramento-San Joaquin Delta, Oroville Reservoir regulated flows would not be required during the initial stages of project development. This observation led to detailed studies by Bechtel of water available in the Delta under present and future conditions of development without Oroville Dam. Details of the methods used and the results of this study are discussed later in this chapter.

Flood Control by Oroville Dam and Reservoir

The benefits of flood control are discussed in the State's Report in general terms, but are not evaluated dollarwise. Accordingly, no credit is taken by the State for possible cost allocation to flood control in the financing of Oroville Dam.

The State reserved flood control storage space in Oroville Reservoir for the period November 15 to April 1. The period is in agreement with the time of flood hazard as shown in the U. S. Weather Bureau-U. S. Bureau of Reclamation Cooperative Study Report No. 12, "Probable Maximum Precipitation on Sierra Slopes of the Central Valley of California," March, 1954, and also with the flood records of all Sierra streams. The flood control operation proposed by the State has merit. When applied to the record of historical floods at the dam site, the peak inflows, which ranged up to 230,000 cfs., were modified to outflows not exceeding 100,000 cfs. However, when applied to the maximum design flood under the assumed conditions, the peak inflow is not as greatly modified as might be desired in routing the flood through the reservoir. Possible alternatives to spillway operating procedures and spillway design capacity should be further investigated, taking into account the power operation of the reservoir, to see if an over-all saving in costs and/or water stored can be effected.

In the state analysis, it was found that if only water supply demand and flood control operating requirements were to be met by releases through turbines, the resulting electric energy output would not be satisfactory for sale on a firm basis. Therefore, in addition to that power obtained by meeting the total water supply and flood control operating requirements, more water was assumed to be released in the state studies for the sole purpose of generating power to meet the market requirements. The additional water thus released was wasted into Suisun Bay, since an adequate water supply was already available in the Sacramento-San Joaquin Delta to meet water supply demands.

Bechtel concurs with the findings of the State in that the construction of Oroville Dam would bring about an improvement in conditions affecting fish life downstream from the dam. Only a small quantity of additional water would be required to be released from the reservoir for this purpose in very dry months. Without Oroville Dam, conditions would, of course, remain the same as at the present.

Comprehensive studies to evaluate financially flood control benefits which might be creditable to Oroville Dam have been made by the State and the results were published in a bulletin entitled "Report on Feasibility of Feather River Project and Sacramento-San Joaquin Delta Diversion Projects Proposed as Features of the California Water Plan," dated May, 1951.

A similar study of flood control benefits which might be expected from storage on the Feather River was made by the Sacramento District of the Corps of Engineers and the results were published in "Comprehensive Survey Report of the District Engineer" and the Supplement thereto, dated 1945 and 1948, respectively.

The basic assumptions and the procedures followed in the development of these studies were different with the result that the estimated annual flood control

benefits are not within reasonable agreement. The findings of both agencies do emphasize, however, that the average annual flood benefit which might be credited to Oroville Dam is significant. It is therefore recommended that a comprehensive reanalysis of this entire subject be made using the standard flood control procedures currently in use by the Corps of Engineers.

Availability of Water in Sacramento-San Joaquin Delta for Feather River Project Export

The water available for the Feather River Project is defined as the net amount of water available in the Delta at the point of diversion, after considering net stream flow after upstream irrigation and other uses, imported waters, other export demands, and flows for salinity control and for navigation.

Those factors which determine the net water available at present, or in the near future are placed into two classifications: (1) those items which make up the water supply, and (2) those items which make up the demand for water before any Feather River Project exports can be made. All of the major factors considered are listed below according to the above classifications.

Sources of water supply

Net stream flow from the Sacramento-San Joaquin River system at the rim of the Delta.

Net available water imported from the Trinity River Basin.

Water demands and mandatory flow requirements

Consumptive use of water in the Delta and in the Delta Uplands.

Minimum flow of water in Sacramento River for navigation requirements.

Flow of water from the Delta for salinity control.

Use of water for irrigation and other purposes along the Sacramento and San Joaquin Rivers systems upstream from the Delta.

Irrigation use of water in the Sacramento Canals Unit and in the Folsom Service Area.

Exports of water from Delta to supply Central Valley Project demands as follows:

Contra Costa Canal;
Exchange Agreement; and
Delta-Mendota Canal Service Area.

In order to determine the amount of water available at the diversion point in a complex system such as the Sacramento-San Joaquin Delta, the usual procedure is to make a flow routing, taking into account all of the important determining factors. This is necessary because of the fact that both water supplies and demands are fluctuating continuously. The State made a month-by-month routing of water supplies in the Delta coordinated with required Feather River Project diversions to the south. A summary of this routing is tabulated in Appendix E-2 of the State Report. The state study included use of Feather River storage in Oroville Reservoir. The computations were made on a monthly basis in three principal steps; as follows:

Determination of the contributions of individual streams tributary to the Sacramento and San Joaquin Rivers, as measured at the rim of the Central Valley.

Determination of the total water reaching the Delta.

Determination of the water available at the Feather River Project diversion point.

The State's routing was based on coordinated operation of Shasta and Folsom Reservoirs of the Central Valley Project and separate operation of Oroville Reservoir. Releases from the former reservoirs were based on criteria enumerated on pages 18 and 19 of the State Report. Releases from Oroville were based on meeting the demands on Oroville Reservoir as discussed heretofore, in this chapter.

The State's routing shows that with Oroville Dam in operation there is an adequate water supply for Feather River Project demands. Bechtel concurs in this finding. However, there are two aspects of the State's studies which warrant specific comment in order to present a clear picture of the water available for export from the Delta.

First, the state criterion for operations of Pumping Plant No. 1 and San Luis Reservoir was originally based on use of the surplus capacity of the Delta-Mendota Canal plus an additional 7,000-cfs. canal. When an 11,000-cfs. canal was substituted for this combination, no new detailed routings were made by the State. As a result, with the increased capacity provided by the separate 11,000-cfs. canal, there would be periods when reservoir levels were below maximum and more water could be stored in San Luis Reservoir than shown by the State. Water in excess of salinity repulsion flows could then be conserved to a greater degree. It is believed that a recalculation of the State's data using the 11,000-cfs. canal in the same manner as used by Bechtel would yield results agreeing substantially with the conclusions set forth in the following paragraphs.

Second, Column 10 of Appendix E-2 of the State Report is headed "Water Specifically Required from Oroville Reservoir to Supply Feather River Project and Central Valley Project Uses and Diversions." Column 2 of the same table excluded all of the flows of the Feather River except return flows from irrigation diversions to the Feather River Service Area. The impaired unregulated flows of the Feather River along with other water available in the Delta, if fully coordinated with maximum possible utilization of San Luis Reservoir, and the 11,000-cfs. canal, could

supply a substantial portion of the demand listed in Column 10, referenced above.

Bechtel made several detailed routings to determine the availability of water in the Delta. All basic figures used in the Bechtel routing studies were taken from the month by month routing studies of the State as tabulated in Appendices E-1 and E-2 of the State Report. Unless otherwise indicated, the Bechtel assumptions were the same as those previously noted as being listed on pages 18 and 19 of the State Report. The assumptions used and/or considered by Bechtel which differ from those used by the State are enumerated and discussed below.

The maximum possible use was made of San Luis Reservoir. Whenever storage capacity was available in the reservoir and water was simultaneously available in the Delta, such water was routed downstream up to the 11,000-cfs. capacity of the Delta-San Luis Canal.

The minimum flow requirement for repulsion of salinity encroachment has been the subject of a great deal of investigation and study by others in recent years. The results of these investigations have shown minimum values required for this purpose ranging from 1,100 cfs. to 6,000 cfs. under various conditions. The more recent figures for average conditions range between 2,500 cfs. and 4,500 cfs. At the present time a comprehensive test program is in progress which, it is believed, will develop some conclusive results.

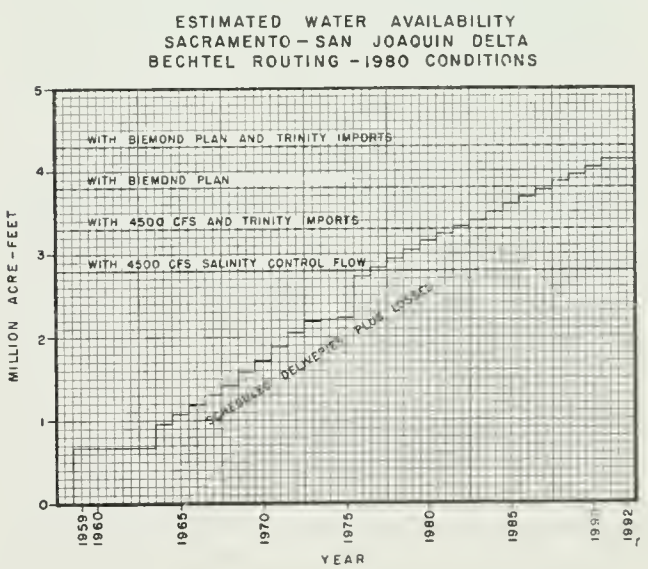
In the Feather River Project studies, both the State and Bechtel used a value of 4,500 cfs., which is conservative. Precedent for the use of 3,300 cfs. presently exists (1) in that the Bureau of Reclamation is currently using 3,300 cfs. as the requirement for salinity repulsion in the operation of the Central Valley Project, and (2) in a statement contained in the report on "Feasibility of Construction by the State of Barriers in the San Francisco Bay System," March, 1955. This statement indicated that it had been determined that 3,300 cfs. is the portion of the surface inflow (excluding unmeasured accretions within the Delta) which must pass through the Delta into Suisun Bay to maintain the chloride concentration below 1,000 parts per million 0.6 miles below Antioch.

The Trinity Division Project has been approved by Congress and the first appropriation has been made. The net annual irrigation benefit of Trinity when integrated with the Central Valley Project would be 1,190,000 acre-feet. The average annual diversion of water is estimated to be 704,000 acre-feet. The Bureau of Reclamation proposes that 665,000 acre-feet would be allocated to the Sacramento Canal Service Area and that the remainder totaling 525,000 acre-feet could be used to serve Central Valley Project demands south of the Delta, such as the Delta-Mendota Canal Service Area or their proposed San Luis unit. It is possible that if the new development in the San Joaquin Valley is entirely by the State, that the latter water allocation in conjunction with other CVP water releases could be obtained by the State to meet the supplemental water requirements of the Feather River Project. No basis exists which would enable this alternate source of water supply to be evaluated with the water benefits to be derived from Oroville Dam and such considerations are beyond the scope of this report.

Construction of the Biemond Plan, as presently outlined, including the salt water barrier at Junction Point and the separate channels for the Sacramento and San Joaquin waters, would increase the net quantity of fresh water available for export from the Delta. Reduction of the assumed salinity control outflows to a minimum of about 500 cfs. would result in a theoretical saving of approximately 240,000 acre-feet per month. Since the San Joaquin River would not be connected to the fresh water system, its waters would not be available for export from the Delta, and a loss of about 20,000 to 40,000 acre-feet per month would be sustained during the critical low flow period. Thus, the Biemond Plan would result in a net saving of about 200,000 acre-feet per month in the low flow period. Considering a low flow period of from four to six months, the annual increase in usable water supply would be about 1,000,000 acre-feet.

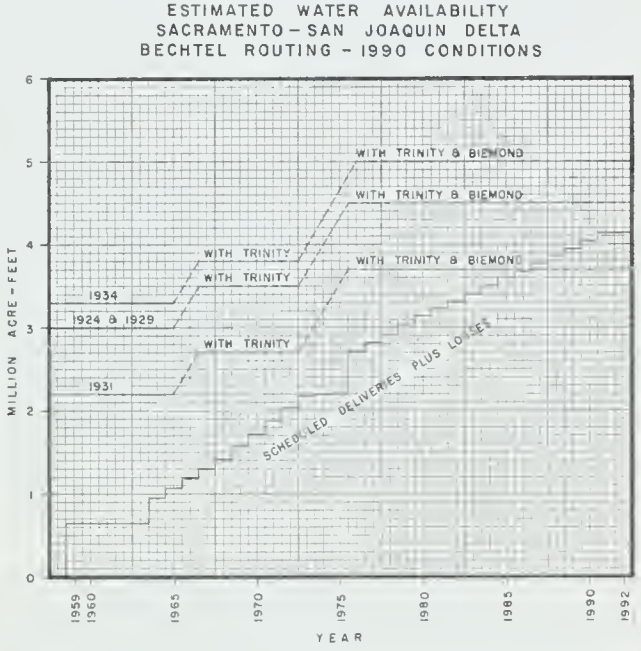
The graph that follows shows the estimated water availability in the Sacramento-San Joaquin Delta for Bechtel routing and 1980 conditions assuming that the Trinity Project and the Biemond Plan would increase the availability of water in the Delta for the Feather River Project. The graph is based on the water year 1931 which was selected because it was found to be the most critical during the 1921-1951 period studied. In developing the curve, consideration was given to scheduled diversions, including conveyance losses. The following was assumed:

1. No Feather River Storage at Oroville Dam Site.



2. Pumping from the Delta as required up to 11,000 cfs.
3. Maximum San Luis Reservoir storage of 2,100,000 acre-feet.

The following graph shows estimated water availability in Sacramento-San Joaquin Delta for water years 1924, 1929, 1931, and 1934 which are the four most critical years of the 1921-1951 period studied. This graph considers scheduled diversions, including conveyance losses and applies to Bechtel routing and 1990 conditions. The graph also indicates the approximate year when supplemental water in the Delta will be needed in order to satisfy the demands of the Feather River Aqueduct on the assumption that the Trinity Project and the Biemond Plan would increase water availability in the Delta and that these projects would be completed as indicated on the graph. The same basic assumptions were used in developing this graph as were used to show 1980 routing.



For the comparative analysis as presented in this report, no Trinity Project or Biemond Plan water was considered to be available for Feather River Project export from the Delta. Exclusion of these potential supplemental waters introduces another conservative factor in the determination of water available for export from the Delta, and the date to which a supplemental water supply is required, in order to satisfy the Feather River Project demands.

Results of Studies of Water Supply by Bechtel

Using the same base water supply figures as the State, but without Oroville Dam, and the anticipated 1980 water supply demands in all areas, a routing was made which showed no significant deficiencies in any of the dry years of the 1921-51 period studied.

The State's Report indicates that only certain areas received allowable dry year deficiencies. It is believed, however, that all irrigated areas served by the project should absorb a proportionate share of any limited deficiency of water supply for irrigation which might occur in an abnormally dry year.

WATER QUALITY

Introduction

In the presentation of water quality in the State Report, the water quality requirements and the quality of water delivered are covered for each of the general uses of water, both in the Feather River at Oroville and in the Sacramento-San Joaquin Delta. The principal uses discussed are domestic, industrial, and irrigation. For each particular use, it is necessary to consider the bacteriological, physical, and chemical aspects of water quality.

Quality Standards

The nationally accepted standards for treated domestic water are as shown in the State Report. It has been assumed that these standards also apply to water for industrial uses. Where they do not, the industries concerned are presumed to provide the necessary special treatment.

The standards for Classes I, II, and III irrigation waters, for fish and wildlife preservation, and for recreational purposes are also presented in the State Report. These standards are also believed to be generally applicable, as presented.

Quality of Feather River Water

After a review of the studies by the Division of Water Resources, as well as on other available information, Bechtel agrees that the water quality of the Feather River is satisfactory and suitable for all normal purposes. Suitable uses include irrigation, recreation, domestic use after minor treatment to remove bacterial contamination, fish and wildlife, and recreational benefits will be realized when Oroville Dam is constructed.

In order to preserve the quality of Feather River water in the future, the State contemplates control of wastes discharged into the river. This is planned not only for the Feather River but for the entire Sacramento-San Joaquin system.

Quality of Water for Diversion From the Delta

Water quality in the Delta has been a serious concern for many years and the magnitude of the problems involved precluded a detailed review of the situation by Bechtel in the short time available. Accordingly, the problem has been considered only in its broad phases.

In order to satisfy the bacteriological and physical quality standards for domestic and industrial purposes it will be necessary and sufficient to provide usual municipal treatment of the water at the points of use, as the State contemplates. Furthermore, with suitable control of waste discharge it is believed that the bacteriological quality for irrigation purposes will remain satisfactory without any treatment. Chemical quality of the Delta waters is then the remaining consideration and will be the only phase of water quality discussed in the following sections.

The quality of water at any point in the Delta and particularly the quality at the intake of the Feather River Aqueduct is determined by the factors listed below.

The quantity and quality of inflow from Sacramento River.

The quantity and quality of inflow from San Joaquin River.

Rising connate or spring waters and other pollutants originating in the Delta.

Salinity encroachment from Suisun Bay.

The degree of intermixing of the various waters.

The Sacramento River and its tributaries contribute the largest volume and by far the best quality of the inflows to the Delta. This water is only slightly degraded by dissolved salts from return flows resulting from irrigation, even in the summer months when the total flow is relatively small. Rising connate waters or springs and degraded irrigation return water are the principal sources of pollution within the Delta itself.

The San Joaquin River, on the other hand, supplies much less total flow to the Delta than the Sacramento River. The quality provided is good during times of high runoff, but becomes poor during the low flow periods when almost all of the flow is comprised of return flows from irrigation. Chloride content has been used by the State, and in this report, as an indicator of dissolved salts in such return flows as an indicator of water quality. However, as stated in the State Report, this practice neglects the effect of other dissolved salts, including the carbonates and sulphates. The relative percentage of the various salts will vary from time to time, so that the chloride content may or may not always give a good indication of the water quality resulting from degradation by irrigation return flows. As applied to salinity encroachment, chloride content is a good indicator of quality.

Charts showing stream flows and corresponding chloride concentrations in the Sacramento and San Joaquin Rivers at the edge of the Delta are included on Plate 15 of the State Report and on Plate 5 of the Division of Water Resources Bulletin 27.

Salinity encroachment into the Delta from Suisun Bay is induced primarily by flow through the Delta channels caused by fluctuations in ocean tides and it is repulsed by the total stream flow out of the Delta. A static condition with a definite limit to salinity encroachment is never achieved, however, since both tides and outflows from the Delta vary continuously. Values of flows necessary for salinity control are discussed elsewhere in this chapter.

The determination of the degree of dilution and intermixing of San Joaquin River, Sacramento River, and Suisun Bay waters at various points in the Delta is a very complex problem which is not thoroughly understood at the present time, despite many comprehensive investigations by the State and the various governmental agencies. There is now general agreement with respect to some of the more important influencing factors and the test network which is now in operation is believed to be an effective method of obtaining the additional information necessary.

In considering the problems of water quality in the Delta, Bechtel has considered the report on "Feasibility of Construction by the State of Barriers in the San Francisco Bay System," dated March, 1955. Particular attention was directed to the "Biemond Plan," which has been recommended by the State Division of Water Resources for more detailed study, as a feasible solution to most of the salinity problems in the Delta. Bechtel concurs in those recommendations and understands that further study is presently in progress by the State Division of Water Resources.

The chemical analyses of water diverted into the Delta-Mendota Canal by the U. S. Bureau of Reclamation as shown for the years 1952 and 1953, in the Reports of Sacramento-San Joaquin Water Supervision, published by the State, are indicative of the quality of water which will be available for diversion through the Feather River Project. A record of water quality in Italian Slough, where the Feather River Aqueduct intake is to be located, is given on Plate 15 of the State Report and indicates that the present Delta water is satisfactory for Class I irrigation use.

It is understood that the U. S. Bureau of Reclamation has had difficulty in meeting the "water quality" requirements of the 1939 Exchange Agreement for the following reasons:

> The Exchange Agreement calls for the delivery of waters such that "The weighted annual average of dissolved solids in substitute waters delivered to contracting companies pursuant to (the) contract shall not exceed by more than thirty-five percent (35%) the weighted annual average of dissolved solids which would result if all such waters had been taken from the Sacramento River at the head of Snodgrass Slough * * *."
>
> The operation of Shasta Reservoir has improved the quality of Sacramento River water at Snodgrass Slough, while the quality of San Joaquin River water has deteriorated.
>
> The resultant, mixed water is claimed to be of satisfactory quality and as good as it was when the

Agreement was enacted (1939), but the measuring standard has changed, giving rise to the present predicament.

The State Report indicates that 178 ppm. of chloride is the maximum allowable concentration for Class I irrigation waters on deep, pervious soils, but past records of the Division of Water Resources show that when the concentration of chlorides at Antioch is 1000 ppm. or less, the concentration only a short distance upstream is about 100 ppm. The Division of Water Resources criterion of maintaining 1000 ppm. or less of chlorides at Antioch is therefore on the safe side with regard both to water use in the Delta and to exports from the Delta through the Feather River Aqueduct.

The water quality of the San Joaquin River, after some improvement over a short reach going upstream from its mouth, begins to deteriorate within the Delta. Improvement is again noted further upstream toward the rim of the Delta and continues upstream thereafter. This phenomenon results from the large volume of poor quality drainage water discharged into the Delta channels, rising connate waters as springs in the Delta, and saline return flows from upstream irrigation.

During the years 1945, 1946, and 1948, 1951, 1952, and 1953, the encroachment of saline waters from Suisun Bay was eliminated as a factor influencing the quality of water in the Delta. This was accomplished by salinity control releases from Central Valley Project reservoirs. These releases were begun in 1944 and have prevented significant encroachments since that date, except for slight encroachments in 1947, 1949, and 1950.

If sea water encroachment is eliminated as a factor affecting the water quality in the Delta, the waters of the San Joaquin and Sacramento Rivers and the pollutants originating in the Delta remain the major factors affecting quality. Under this condition, the water quality in the Delta was found to be generally satisfactory, (1) at all times meeting the standards for treated domestic water (250 ppm. of chlorides), and (2) nearly always meeting the standards for Class I irrigation water (178 ppm. of chlorides). However, temporary degradation of water quality below the Class I irrigation water standard is not believed to be critical for the Feather River Project, since deliveries are planned to be made at these times from water of good quality stored in the project reservoirs, primarily San Luis Reservoir. The Bechtel studies showed further that the quality of Delta water near the proposed Delta Cross Channel would be satisfactory for both domestic and Class I irrigation uses even though salinity encroachment had reached the maximum to be anticipated under present conditions.

The construction of separate channels generally as proposed in the Biemond Plan would further improve water quality. Such a system of channels would allow Central Valley Project and Feather River Project exports to be made entirely from the desirable Sacramento River waters. The interior channels of the Delta would be isolated and the San Joaquin River would be used as a drainage channel.

Even without separate channels, the water quality in the Delta probably will not be severely affected by the Feather River Project. Factors tending to improve future quality will be increased summer flows from Central Valley Project reservoirs and improving return flows from irrigation in the Sacramento Valley. A factor tending to produce water of poorer quality will be the increased return flow from newly irrigated lands principally in the San Joaquin Valley under Feather River Project and Central Valley Project development.

Reuse of a portion of the water delivered through Feather River Project facilities will undoubtedly occur as the State has contemplated. Rapid deterioration in the quality of San Joaquin River water has been experienced in recent years due to irrigation of new lands in the San Joaquin Valley. The return flows from these lands have caused a rise in the water table and a consequent increase in the seepage of poor quality groundwater into channels of the river system.

The Feather River Project will first serve the west side of the San Joaquin Valley where the unconfined groundwater is especially high in salts. Therefore, further temporary degradation of the waters at the San Joaquin and west sloughs must be expected for some period after deliveries have begun. This phase of the water quality problem should be investigated further. After a period of time, the quality will probably improve as the excess applied water leaches out the salty groundwaters.

CHAPTER III

ENGINEERING FEASIBILITY AND COST ESTIMATES

INTRODUCTION

A general description of each of the seven routes for the Feather River Project, as proposed by the State, and of Bechtel's four route modifications, is contained in Chapter I. This chapter covers the results of Bechtel's review of the engineering feasibility and estimated costs of each of these routes.

A comparison of the estimated costs prepared by the State and by Bechtel for each of the State's proposed seven routes, and estimated costs of the four Bechtel modifications, are summarized on the following page.

No two of the State's seven proposed routes deliver water to all of the same areas or delivery points nor in the same amounts; therefore, a direct comparison of the State's total costs for the several routes is not a true measure of their respective merits. During the review it was found that estimating procedures used by the State conformed with accepted practices. Differences in anticipated cost reflected in this report are considered to be within the limits of variation which may be expected in separately prepared estimates and calculations which require judgment and opinion.

SUMMARY CONCLUSIONS

Oroville Dam

Although the foundation area for the dam is sheared and fractured, Bechtel believes that there is competent rock at this site for a dam of the height proposed, if excavation is carried to suitable depths, and if consolidation grouting is provided in those foundation areas requiring such work in addition to grouting required for the upstream grout curtain.

Bechtel studies for different heights of dam indicate that the proposed installed kilowatt capacity in the powerhouse will produce revenues which will result in the most economical cost for supplemental water from Oroville Reservoir. The studies indicate that the capacity of the reservoir is well suited to ultimate project water requirements.

The design data for the dam, as proposed, are adequate for preliminary cost estimates but determination of the best dam section for the site must be deferred pending completion of final design studies. Bechtel's review of contraction joints and block size is based on blocks of the same size proposed by the State.

Bechtel agrees that the best location for the spillway is in the natural saddle off the right abutment of the main gravity section.

While final power plant design may result in more efficient utilization of power plant space, the preliminary design as presented will produce an installation which will be feasible. Bechtel concurs with the State's plan for the switchyard.

Bechtel concurs with the requirement for re-regulatory storage below Oroville Dam by two afterbay dams and the locations selected are considered to be satisfactory. It is agreed that construction of power facilities at Afterbay Dam No. 1 would not be eco-

SUMMARY COMPARISON OF ESTIMATED COST

(Includes Interest During Construction at 2.5% per Annum)

Route	Description	State's cost	Bechtel cost	% differential Bechtel compared to State
1	State High Line to Barrett Reservoir	*$1,594,908,000	$1,723,484,000	+8.1
2	State High Line to San Bernardino and Devil Canyon Power Drop	*1,493,147,000	1,597,092,000	+7.0
3	State High Line to Quail Lake and Castaic Power Drop	*1,397,522,000	1,514,688,000	+8.4
4	State High Line to Devils Den—Coastal Line to Castaic Creek	*1,551,988,000	1,606,975,000	+3.5
5	State High Line to Devils Den—Coastal Line to San Jacinto	*1,839,567,000	1,912,740,000	+4.0
6	State High Line to Pastoria Creek—Long Tunnel to Castaic Creek Reservoir	*1,383,841,000	1,495,425,000	+8.1
7	State High Line to Pastoria Creek—Long Tunnel to San Jacinto	*†1,700,233,000	1,810,795,000	+6.5
8	Bechtel Alternate—High Line to Devils Den—Coastal Line to Castaic Reservoir—Extension to Granada Hills Reservoir		1,672,845,000	
9	Bechtel Alternate—High Line to Pastoria Creek—Long Tunnel to Elizabeth Lake Power Drop and Castaic Reservoir—Extension to Granada Hills Reservoir		1,568,511,000	
10	Bechtel Alternate—High Line to Quail Lake and Castaic Power Drop—Extension to Granada Hills Reservoir		1,580,297,000	
11	Bechtel Alternate—High Line to Mile 500—Cherry, Boquet and Haskell Power Drops to Granada Hills Reservoir		1,618,699,000	

* Includes $2,000,000 cost for a portion of the canal from Italian Slough to Pumping Plant No. 1 which was not included in the State's estimates.

† Includes $59,981,000 as estimated by the State for the Alameda-Santa Clara branch with pumping plants and reservoirs, which was not included in the State's estimate for this particular route.

nomically justified because of the large fluctuation of this reservoir in operation.

Significant construction quantities were checked and some minor differences developed. These differences are caused by different assumptions as to field conditions and equipment selection.

Delta Cross Channel

It is concluded that a confined Delta Cross Channel is desirable and its construction is feasible. However, the presently undefined relationship of this proposed channel to various barrier and salinity control schemes makes it impracticable to determine at this time what portion of the physical features or their costs, if any, should be considered as an integral part of the Feather River Project.

Alameda-Santa Clara-San Benito Branch

Bechtel's examination of the Airport Dam site confirms the State's conclusion that this is a potential site. Further subsurface investigations must be made to permit evaluation of foundation conditions.

Bechtel's geological reconnaissance of the Evergreen Dam site confirms the State's concern with the presence of the Silver Creek Fault, and the selection of an alternate location may be required if further investigations should prove the site geologically unsuitable.

No particularly adverse geological conditions that would prevent construction of the aqueduct were found and the location selected by the State is generally satisfactory for determining a reasonable cost estimate.

Structures for the aqueduct are designed in accord with good engineering practice.

Although construction and design data are insufficient for an analysis of the Airport and Evergreen Dams, Bechtel considers that the dam sections assumed are in accordance with accepted practice. The flow-routing studies indicate that their reservoir capacities are adequate.

Bechtel's estimates of quantities show no important differences except in the tunnels.

San Luis Dam and Reservoir

Additional foundation exploration should be made to determine the permeability of the gravelly clay encountered by previous drilling about 140 feet below the surface. Further investigations are also required to determine the type and depth of cutoff required for the dam.

The San Luis Reservoir is required for initial operation of the project and Bechtel concurs that the full reservoir capacity will be required to meet ultimate project demands. The advisability of two-stage construction of this facility as proposed by the State should be re-evaluated at the time that realistic comparative cost estimates can be prepared.

An independent analysis of the dam embankment was made, using the standard methods outlined by the State Engineer. On the basis of this analysis Bechtel concludes that the dam section as proposed by the State would be inadequate. It is also Bechtel's opinion that the design values proposed for earthquake forces should be increased because the dam would be located within a major active fault area. When this is done the safety factor of the State's design is further reduced. Bechtel's studies and preliminary estimate accordingly are based upon a revised section for the dam.

Supplemental subsurface investigations are needed to develop a source of additional pervious material close to the dam site. Soil testing of borrow materials is required for use as a basis in determining final design.

In view of the considerable height of the embankment, its location in a seismic area, and the importance of dependent structures, a modification to permit inspection and maintenance of the full length of the outlet conduit at all times is believed justified.

Because of the limited drainage area, the spillway does not present a major problem and the proposed spillway is considered adequate.

Pumping Plants

There are six main-line pumping plants for Route No. 1 (High Line) and a relift plant for the Alameda-Santa Clara-San Benito Branch. For the ultimate development, the installed horsepower, including spare units, totals 3,328,000 horsepower. For Route No. 4 (Coastal Line) a total of nine main-line plants and the relift plant for the Alameda-Santa Clara-San Benito Branch are required, with a total of 1,733,000 horsepower.

For the ultimate development, the State contemplates using on-peak power at Pumping Plant No. 1 and the relift plant, a small portion of on-peak power at Pumping Plants No. II-A and II-B, and off-peak power in the remainder of the plants, with the exception that one of the six coastal route plants would use on-peak power. Appreciable annual savings in the cost of power could be realized if on-peak power requirements at Pumping Plants No. I, II-A, and II-B could be reduced. An afterbay with regulated storage at the discharge of Pumping Plant No. II-A will contribute materially toward keeping pumping costs at a minimum.

Forebays and afterbays or equivalent storage capacity in the aqueduct should be provided for Pumping Plants No. IV, V and VI.

While the preliminary design drawings and pumping plants specifications prepared by the State are adequate for preliminary design and estimates, a con-

siderable amount of additional study should be applied in the final engineering work to determine unit operational requirements, appropriate sizes and most advantageous disposition of equipment consistent with aqueduct and water supply limitations. While the lifts at Pumping Plants No. V and VI are unusual, they are not without precedent. The desirability of using single casing pump designs as a substitute for two and three pumps connected in series at Plants No. V and VI should be given careful consideration before final design.

While the pump units proposed for the Feather River Project are uncommon in size and number, their design, construction and satisfactory operation are feasible.

Main Aqueducts

Preliminary location of the routes between the intake and the southern end of the San Joaquin Valley is satisfactory when considered for minimum disturbance of existing developments, for initial construction costs, maintenance, and delivery to potential areas of water use.

Bechtel concurs with the State's selection of unreinforced concrete lined canals as reflected by preliminary designs and estimates.

The canal slopes as adopted by the State for the project are generally reasonable and satisfactory for a preliminary estimate.

It is difficult at this stage of development planning to predict the exact numbers of miscellaneous structures such as drains, siphons, bridges, turnouts, checks, wasteways and other canal structures and appurtenances. The State's estimate for these features is, in general, satisfactory. Bechtel has indicated some minor alterations in design and has made appropriate revisions in quantities.

In general, the tunnel quantities estimated by Bechtel are somewhat higher than the State's.

Distribution of Project Water

Because of the complex factors of water distribution in irrigated and urban areas, Bechtel concurs with the State in the following points:

Feather River Project water should be sold at canal side to distribution agencies.

The distribution agency should finance, construct and operate the necessary facilities to receive and distribute the project water.

The patterns of formation and integration of the distributing agencies to best serve the various areas will develop in due course as the needs arise, and it would not be practicable or desirable to outline at this time any long range plan.

The costs of conveyance laterals from the main aqueduct, distribution regulating reservoirs and distributing systems should not be included in Feather River costs.

Project Operation and Maintenance

The basic assumptions from which the State estimated annual costs for motor vehicle expense, major equipment expense and materials and supplies appear to be sound and representative of local practices.

The proposed organization for operation of the project appears adequate except for personnel assigned to Pumping Plants No. I and II.

The allocations for general expense and for operation and maintenance should be increased for reasons set forth in this chapter.

It is felt that the need for permanent housing at Oroville Dam should be reviewed at the time the project is constructed.

Possible Modifications and Alternates

Oroville Dam. The present Delta water flow must be supplemented by an additional source of regulated flow in order for the Feather River Project to meet the ultimate water requirements as proposed by the State. The cost of water from Oroville Reservoir is reasonable when compared with other current supplemental water developments. On the basis of water availability and also of the most economical pumping of the project's requirements, the completion of Oroville Dam can be delayed until water deliveries are estimated to be about 2,500,000 acre-feet annually. Modifying water releases from Oroville Reservoir so that the on-peak power requirements at Pumping Plant No. 1 can be reduced by 97,200 kilowatts will offer a net annual savings of approximately $2,146,000. To accomplish this anual saving in purchased power costs, the dependable generation at Oroville Power Plant is reduced from 410,000 to 380,000 kilowatts.

San Luis Afterbay. Providing an afterbay with a regulated storage of approximately 15,400 acre-feet at the discharge of San Luis Reservoir and Pumping Plant No. II-A will produce a net annual power savings of approximately $1,473,000 which combined with the savings at Pumping Plant No. I would total $3,619,000. The total power net savings throughout the 70-year payout period of the project would be in excess of $134,000,000.

Use of Delta-Mendota Canal. Bechtel's studies indicate that there would be no advantage of incorporating the use of the surplus capacity of the Delta-Mendota Canal in the State's Feather River Project even for an interim period. Based on operational flexibility, total project expenses throughout the payout period, and capacity benefits related to future expansion, the State is justified in building an independent 11,000-cfs. aqueduct from the Delta to San Luis Reservoir.

Bechtel Route Modifications. A comparison of the delivered cost of water for the various alternate routes calculated by the "proportionate use" method, shows that the "High Line" Route to Quail Lake and through the Castaic Power Development produces sufficient advantage in the cost of water delivered to Southern California to warrant adoption if the cost of water is the deciding factor.

In order to arrive at a realistic cost of water, the build-up of water deliveries should be consistent with the predicted requirements of the consolidated service area of the Feather River Project, individual area requirements being met in the order in which they develop. Bechtel schedules of water deliveries consist essentially of the State's schedules, modified to delete proposed Antelope Valley deliveries and to reassign this supply to the San Joaquin Valley. Also Bechtel estimates that the rate of build-up in the San Joaquin Valley will exceed that which is included in the State's Report.

A comparison of the detailed financial results over a 71-year period for the Castaic Power Development Route with those for the Coastal Route, both incorporating Bechtel's operational modifications related to pumping costs and schedule of water deliveries, shows that the cost of water delivered to Southern California via the Castaic Power Development Route would be less costly than if delivered by the Coastal Route.

Cost Estimates and Construction Schedules, Methods Employed

Several approaches were used in reviewing the State Engineer's cost estimates. The first approach was to divide the work into features or sections of the size and character that are customarily offered for bidding in the Western States. Within the limitations of available data and design, estimates of cost similar to a contractor's bid estimate were made for each section or feature. At the same time it was realized that contractor's bid estimates usually are prepared upon detailed plans and specifications.

In the second approach, prices for work of similar character and scope were assembled from actual bids made by contractors in the West Coast area during the period from 1948 to 1955. These were adjusted for the differences in cost indices, so as to be consistent with contract bid prices suitable as a basis of comparison with those used by the State.

Unit prices developed from data applicable to approximately 80 tunnels already constructed and available field data, was used to evaluate the anticipated construction conditions.

For a check on the State's costs for the pumping plants, Bechtel prepared, from past experience and a review of large scale pumping plants recently constructed, sufficient details of the pumping and electrical equipment, structures and installation costs involved, to provide a sound basis for an estimate of cost of the plants required for the High Line, Route No. 1. This review indicated some differences or omissions in the State's assumptions. The estimated costs thus developed by Bechtel for the High Line Route plants were adjusted to fit the plants included in the other proposed routes.

Only the High Line, Route No. 1, was included in the State's Report in complete detail with estimated quantities and prices for each item of work. The estimated costs for the other proposed routes were prepared from less detail, but on the same general basis. The State in accomplishing the layout and estimate for the High Line had done considerable work in mapping and locating the aqueduct line in field and office, particularly in the San Joaquin and Antelope Valleys. Detailed reconnaissance work was not carried out for the other proposed routes. All aqueduct locations were generally laid out on U. S. or State Geological topographic maps. The paper locations were reviewed by Bechtel personnel in the field, and the surrounding geology was carefully considered.

For major structures such as Oroville Dam and Powerhouse, San Luis Reservoir Dam, the Pastoria Creek Tunnel, and the Long (1870) Tunnel, the State prepared definitive plans showing details of methods of construction, and plant and equipment layout.

The State had prepared a detailed appraisal of the costs of right-of-way for the High Line, Route 1. This appraisal, covering all 12 counties crossed by the project, was made available to Bechtel for use in this review. Bechtel reappraised a test section consisting of all estimated costs of right of way, with severance damages as appropriate, throughout the west side of the San Joaquin Valley. The results of the reappraisal of the test section indicate that the State's estimated right-of-way acquisition costs are approximately 8 percent low. Bechtel therefore accepted the State's appraisals for the entire route as being a sufficiently accurate base, and added 8 percent to the amounts shown in the State's estimates for procurement of appropriate right-of-way interests.

No provision has been made by the State, nor by Bechtel for escalation of costs (or revenues). Costs for construction work over the past five years indicates an upward trend.

No attempt has been made to estimate cost variations over the long construction program on the assumption that, except for very short term variances, there will be no major change in the general relationship between economy and cost.

Comment on State's Cost Estimates

The State estimates include an indirect cost item of "contingencies," which is normal practice, and is

to cover amounts needed to provide for any increases which might result from inadequate or unavailable data on foundation conditions, and undesirable underground conditions for tunnels and canals which would not be readily ascertainable. This item also provides for errors and omissions inevitable in a preliminary engineering and financial report of this magnitude. The total allowance by the State for "contingencies" varies among the several proposed routes from $138,229,000 to $224,724,000. These amounts are of considerable magnitude, however it is believed that these amounts are reasonable when considering the present status of design and exploration work.

Pumping Plants No. III, IV, V and VI, between Wheeler Ridge and Pastoria Creek have no forebays or afterbays beyond Pumping Plant No. III or surplus capacity in this reach of aqueduct to level out irregular irrigation canal flows in the San Joaquin Valley into intermittent pumping flows, at the same time furnishing regulated supply for combined domestic, industrial and irrigation demands south of the Tehachapi Mountains. To supply these facilities, Bechtel believes that a sum of approximately $35,000,000 should be included in the estimates of the proposed Routes No. 1, 2, 3, 6 and 7, and Bechtel's modified routes 9, 10 and 11, however no such allowance has been included in Bechtel's estimates.

Pumping Plants No. 1 to 5 inclusive, on the Coastal Line Aqueduct, are planned for operation on off-peak power. The canal, siphons and tunnels are layed out on a continuous flow basis. No forebays, afterbays, nor regulatory storage are provided in the State's estimate. In the detail data book supporting the State's summary of cost for the Coastal Line, an item of $30,000,000 was set up for such facilities, but it was not identifiable as such in the State's cost summary. Bechtel believes that these facilities are necessary, and an estimated cost allowance is included for such facilities. This applies to State's alternate Routes No. 4 and 5.

The State's supplementary report, "Office Report on Design and Cost Estimates," indicates the facilities which would be required to convey water from the Sacramento River to the intake channel leading to Pumping Plant No. 1, and that the cost for these facilities would be about $33,000,000 as set up in the Junction Point Barrier Plan. By reducing these facilities to what the State considered a minimum, the State arrived at a cost for these reduced facilities of $8,320,000. Bechtel checked the State's cost estimate insofar as practicable.

Cost estimates are included in this chapter for Bechtel's suggested route modifications. It should be noted that these estimates contain no allowances for distribution works in either irrigated or urban areas. Neither is there any allowance for drainage systems in irrigated lands. Considerable cost will be incurred to provide these facilities.

General Comment

Examination of comparative costs for sections of the aqueduct indicate that the cost per cfs. of water is inordinately high for some sections. While this is partially explained by the smaller size and more difficult location of certain sections, Bechtel suggests that it should be the subject of further engineering and economic study, in final design, to see whether the location of each section is the best which may be secured with proper safety in operation.

The report of the State Engineer sets forth a program for the step construction for the High Line Route, from the Delta to Barrett Reservoir. This construction schedule is also shown graphically in the State's Report. Bechtel is in general accord with the feasibility of this program, with some reservations which are set forth below. The same comments apply to the step construction program for the other four routes, No. 2, 3, 4 and 6, also described in the State's Report.

The reservations with respect to the State's construction schedules are as follows:

> A period of approximately one year after authorization of construction of the project will be necessary for the extensive exploratory drilling and other field investigations, and preparation of designs, contract plans and specifications before major construction work can be started.
>
> In Bechtel's opinion the construction of the aqueduct between the intake and the northern portion of San Joaquin Valley can be constructed within the scheduled three-year period as proposed by the State. However, to complete the entire aqueduct from the intake to Wheeler Ridge within the State's three-year schedule is very optimistic, although not impossible of attainment. This reach of aqueduct involves some 140 million cubic yards of material to be excavated, of which nearly 10 million cubic yards are of rock formation, and the trimming and lining with concrete of about 280 miles of canal. This type of construction requires large custom-built equipment, not in general use, but manufactured to specifications when purchased. Presently, there are only a few manufacturers who have had previous experience in the production of such equipment. Furthermore, in unprecedented amount of material such as cement, reinforcement steel, and other metal items will be required. These items are currently in short supply.

Bechtel recommends that serious consideration be given to the above comment in the final preparation

of a construction schedule so that the project may proceed in an orderly manner with maximum economy to the State.

OROVILLE DAM AND RESERVOIR, POWER PLANT AND AFTERBAYS

General Description

Primary storage for development of the Feather River Project's ultimate supplemental water supply would be afforded by a proposed dam on the Feather River, 1.7 miles below the junction of the north and middle forks of the stream and 5.5 miles above the City of Oroville, in Butte County.

The massive concrete gravity dam would be 730 feet high above streambed, 680 feet thick at the base, 4,930 feet long, and would contain approximately 14,000,000 cubic yards of concrete. The reservoir would have a capacity of 3,500,000 acre-feet. A powerhouse with an installed capacity of 440,000 kilowatts would be constructed at the toe of the dam.

Two afterbay dams would be constructed at sites 5 miles and 10½ miles downstream to reregulate the fluctuating discharges through the power plant.

Geology

The site was examined by Bechtel, the results of the State's subsurface exploration were carefully reviewed and the State's geological reports were studied.

Oroville Dam foundation area is of metamorphosed sedimentary and igneous rock, which is predominately an exceptionally hard, medium to fine-grained amphibolite. The rock is sheared and fractured, and has developed a foliation which strikes approximately across the river, dipping steeply upstream at the dam site. Joint systems are pronounced, and some joint planes are open.

Bedrock is exposed at the river's edge and for a short distance up the valley sides, and apparently lies at shallow depth beneath the river. However, the zone of weathering becomes progressively thicker on the higher slopes and sound rock is deeply buried at the higher elevations. The upper portion of the dam would abut against the deeply weathered upland surfaces. The depth to sound rock is greatest beneath the upper portion of the left abutment, but deep stripping will be required over the entire foundation area except near the river. This is indicated by drill cores already taken and examination of the rock in the explored area and especially in the exploration drifts located in both the right and the left abutment areas. The jointed and sheared zones will require special treatment. However, competent rock is available for a dam of the height proposed if excavation is carried to suitable depths, and if consolidation grouting is provided in those foundation areas requiring such work. Such grouting would be in addition to the required upstream grout curtain.

Capacity Considerations Oroville Reservoir and Power Plant

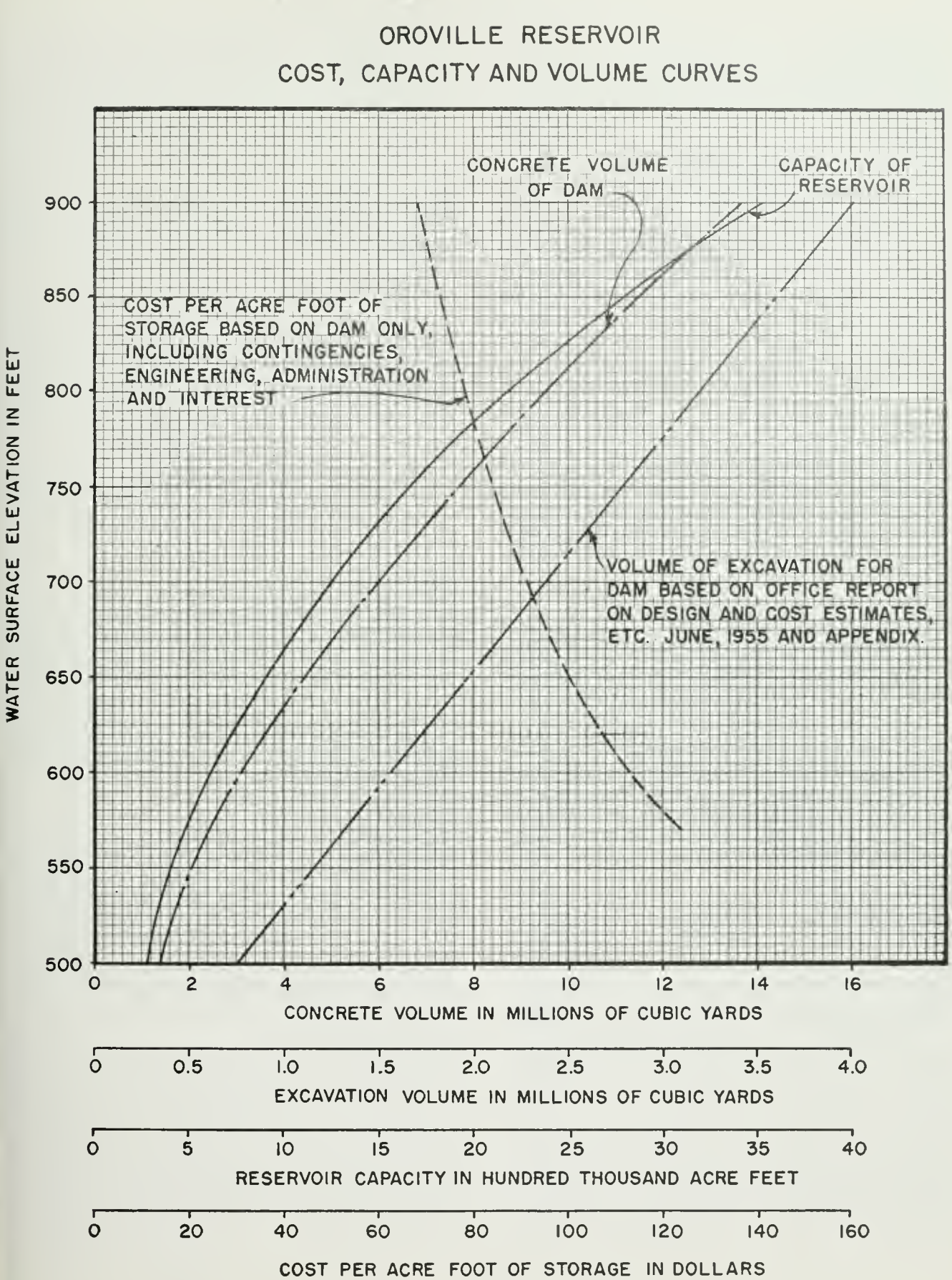
Bechtel studies considered the relative economics of Oroville Reservoir and Power House with respect to the height and capacities recommended by the State. Examination of the cost estimates revealed that expenses related to land acquisitions, right of way and relocations, which costs would be over 28 percent of the Oroville Dam and Power Plant, would be reduced only a slight amount by lowering the dam crest from elevation 910 feet to an elevation such as 665 feet. Such a reduction would reduce the storage capacity from 3,523,000 acre-feet to approximately 1,000,000 acre-feet. The cost of constructing the Dam for the lower elevation on an acre-foot water storage basis would increase approximately 45 percent. The potential power development would decrease approximately 58 percent. With power generation and no storage being allocated to flood control in the smaller reservoir, the firm irrigation yield would decrease approximately 68 percent. Total annual costs in excess of power revenues for the 665 feet elevation dam would be excess of those for the 910 feet elevation dam.

The annual expenses for a dam constructed solely for Feather River Project water supply with no power generating facilities would be more costly than the annual expenses in excess of power revenues for Oroville Dam as proposed by the State. The relative economics are the same for dam elevations ranging between 665 feet and 910 feet.

The following curves show related factors for various water surface elevations at Oroville Dam, which include:

Capacity of reservoir;
Concrete volume of dam;
Volume of excavation for dam; and
Cost of dam per acre-foot of storage.

Bechtel studies for different heights of dam indicate that the proposed installed kilowatt capacity in the powerhouse will produce revenues which will result in the most economical cost for supplemental water from Oroville Reservoir and the studies indicate that the capacity of the reservoir is well suited to ultimate project water requirements, and Oroville Reservoir in conjunction with the San Luis Reservoir would assure the Feather River Project a firm source of water supply through a three- or four-year adverse water period when the project is in full operation.


OROVILLE RESERVOIR
COST, CAPACITY AND VOLUME CURVES
CONCRETE VOLUME OF DAM
CAPACITY OF RESERVOIR
COST PER ACRE FOOT OF STORAGE BASED ON DAM ONLY, INCLUDING CONTINGENCIES, ENGINEERING, ADMINISTRATION AND INTEREST
VOLUME OF EXCAVATION FOR DAM BASED ON OFFICE REPORT ON DESIGN AND COST ESTIMATES, ETC. JUNE, 1955 AND APPENDIX.
WATER SURFACE ELEVATION IN FEET
900
850
800
750
700
650
600
550
500
0 2 4 6 8 10 12 14 16
CONCRETE VOLUME IN MILLIONS OF CUBIC YARDS
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
EXCAVATION VOLUME IN MILLIONS OF CUBIC YARDS
0 5 10 15 20 25 30 35 40
RESERVOIR CAPACITY IN HUNDRED THOUSAND ACRE FEET
0 20 40 60 80 100 120 140 160
COST PER ACRE FOOT OF STORAGE IN DOLLARS

Dam Design

Bechtel made independent analyses of the principle factors of the design proposed by the State.[1] The design criteria as set forth by the State Report were found satisfactory, and in accord with sound engineering practice. On the basis of the information available, Bechtel is in substantial agreement with the State's estimate of the depth of excavation necessary to reach an adequate foundation.

The section proposed for Oroville Dam in the State Report is adequate for preliminary purposes but will no doubt be improved and refined in final design.

The State[2] recognizes the importance of the dissipation of heat generated by hydration of the cement in a dam of this size and outlines the general plan for handling the problem. Bechtel is in substantial agreement with the State's conclusions.

The State Report proposes that longitudinal contraction joints be at 130-foot intervals and that transverse joints be 60 feet apart. Thus the dam would be composed of a series of adjoining keyed columns, each having a cross-section of about 60 feet by 130 feet. Determination of the block size for a large dam is an empirical matter, and the joint layout and design proposed by the State is considered to be satisfactory for preliminary purposes.

Spillway and Flood Control Structures

Bechtel made independent studies of the flood hydrology of the Feather River above Oroville dam site and concurs that the spillway capacity of 500,000 cfs., as proposed by the State, is adequate and reasonable. It is also agreed that the best location for the independent combined automatic spillway and flood control structure is in the natural saddle off the right abutment of the main dam. It would be necessary to improve, by excavation only, a natural ravine leading from the spillway structure to the Feather River for a distance of approximately 4,000 feet. This channel could be made adequate for handling the maximum design flows.

The spillway gates as proposed are of an unusual design. However, the present design is preliminary and there will be opportunity for study of other types of gates before final decision.

To maintain the normal flood control reservation in Oroville Reservoir, water would be discharged through a special section of the spillway structure, consisting of five top-seal radial gates of proven design. The spillway section and its appurtenant works are adequate to fulfill their respective functions.

[1] *Office Report on Design and Cost Estimates of Oroville Reservoir, Dam, Power Plant, and Afterbays*, Appendix, State of California, Division of Water Resources, Sacramento, California, June, 1955, Dwg. No. OD-4-1.

[2] *Office Report on Design and Cost Estimates of Oroville Reservoir, Dam, Power Plant, and Afterbays*, State of California Division of Water Resources, Sacramento, California, June, 1955, pages 13-20.

Power Plant

The location and arrangement of the proposed five-unit power plant at the base of Oroville Dam is generally satisfactory. However, Bechtel review indicates the possibility of somewhat more efficient utilization of power plant space and in the realignment of penstocks, to result in elimination of exposed portions thus providing for complete penstock embedment within the mass of the dam. The preliminary design presented in the State Report is reasonable for estimating costs.

Low-level Outlets

Releases from Oroville Reservoir would normally be made through the Power Plant. When downstream water obligations could not be totally fulfilled by power plant discharges, the deficiency could be made up by releases through the two 84-inch diameter low-level river outlets. The state-proposed hollow jet valves for these outlets are satisfactory.

The problem of satisfying downstream requirements for the temporary period following the closure of the construction diversion openings requires additional study.

Palermo Canal

Creation of Oroville Reservoir will submerge a portion of the existing Palermo Canal, now located in the left abutment area of Oroville Dam. A new headworks for this 35-second-foot irrigation canal will be provided by two 24-inch diameter conduits equipped with hollow jet valves. This arrangement is feasible. A cooperative agreement regarding operation of this new canal headworks must be worked out with the Oroville-Wyandotte Irrigation District.

Switchyard

The state-planned high-voltage outdoor switchyard, proposed for construction in an open position off the left bank of the river, is in accord with good engineering practice. The standard unit design proposed by the State was reviewed and checked by Bechtel. The installation will permit modifications and additions as it becomes desirable, with the growth of the project and as improvements to equipment are developed.

Afterbay Dams

It is estimated that 23,000 acre-feet of storage would be necessary to reregulate the fluctuating power plant discharges. Since conditions immediately downstream from Oroville Dam are not favorable for creation of a single afterbay reservoir of this capacity, the State has proposed that reregulatory storage be provided in two afterbay reservoirs, Bechtel is in agreement with this decision.

Afterbay Dam No. 1 would provide a reservoir of 5,200 acre-feet capacity. An approximately 100-foot high, straight gravity concrete dam is proposed by the State. This would have a 600-foot-long free-overflow spillway with a capacity of 500,000 cfs., the same capacity as the spillway of the main dam.

The State's preliminary exploration indicates that competent rock for a dam of this height is present, but these investigations were insufficient to be conclusive. Additional exploration will be necessary before final determination can be made of the design. Therefore, for preliminary estimating purposes Bechtel has accepted the State's design as the general type of dam for use at this particular location.

Afterbay Dam No. 2 would create a reservoir having a capacity of about 17,700 acre-feet. This dam would have a maximum height of approximately 40 feet and would be approximately 5,180 feet long. Beginning at the right abutment, this would be made up of 3,300 feet of dredge tailing fill, 1,000 feet of concrete paved drum-gated spillway section, a 72-foot outlet structure section, and about 800 feet of dredge tailing fill in the left abutment area.

The spillway section for Afterbay Dam No. 2 is designed to pass only about 100,000 cfs. without overtopping. Since this dam is not of a type which would withstand overtopping, the State Report takes cognizance of the possibility of the dam being damaged by a larger flood, and concludes that it would be more economical to accept the risk of damage to the dam, than to construct a spillway capable of passing the design flood of Oroville Dam.

If only risks to the structure were involved, this would be a reasonable conclusion. However, if this embankment were overtopped, there is a strong possibility that a section of the dam would fail with a relatively sudden release of a large volume of water under more than 40 feet of head. The resulting possibility of loss of life and property in the highly developed downstream area would constitute an intolerable risk. It is therefore concluded by Bechtel that the proposed design is not acceptable.

A dam to safely pass the full design flood would cost a considerable amount more than the dam proposed by the State. However, data for making a design upon which to base a realistic cost estimate are not available and Bechtel has therefore estimated the costs based on the State's design with the reservation that the cost allowances are insufficient for this particular minor feature of the over-all project.

Power Generation at Afterbay Dams

The State concluded and Bechtel agrees that because of the large fluctuations in the water surface elevations in these afterbays, power development would be uneconomical.

Comparison of Quantities

Bechtel's findings are generally in agreement with the State's estimated quantities for construction of Oroville Dam and its appurtenant works. The principal differences are as follows:

Oroville Dam. The Bechtel estimate of foundation excavation is 472,000 yards greater than the state figure. Bechtel's measurements were scaled from Drawing No. OD-2-2, which shows ground surface elevations approximately seven feet higher than those used by the State. In view of this uncertainty as to the amount of stripping which may be required, it would be prudent to use the larger figure.

The state quantities for drilling and grouting are adequate for a grout curtain only and since considerable foundation consolidation grouting will also be required, an allowance for this has been included in the Bechtel estimate.

Bechtel's approximate analysis of reinforcement required around the penstocks indicates some 1.5 million pounds less than the state figure. Because of the large size and the high head on the penstocks, the Bechtel cost estimate provides tractor gates, with individual hoists for each gate, in lieu of the butterfly valves used by the state.

Spillway, Outlet Works, and Earth Dams. The Bechtel estimate of 81,000 cubic yards of mass concrete exceeded the state estimate by 66,000 cubic yards. This is apparently due to a difference in division between mass and reinforced concrete, since the Bechtel estimate for reinforced concrete is less than the state's by 26,500 cubic yards.

COMPARATIVE SUMMARIES OF COST

OROVILLE DAM, RESERVOIR, POWER PLANT, AND AFTERBAYS

	State	Bechtel
Main Dam	$185,581,000	$194,019,000
Power Plant	27,926,000	28,478,000
Spillway	10,854,000	10,451,000
Afterbay Dam No. 1	2,938,000	4,240,000
Afterbay Dam No. 2	3,089,000	3,562,000
Permanent Buildings and Roads	772,000	400,000
Fish Hatchery	440,000	440,000
Acquisition of Lands and Improvements	2,473,000	2,721,000
Acquisition of Big Bend Power Plant	27,000,000	27,000,000
Relocation of Western Pacific Railroad	30,608,000	31,911,000
Relocation of Feather River Railway	2,651,000	2,410,000
Relocation of State Highway Sign Route 24	5,030,000	4,830,000
Relocation of County Roads	3,004,000	4,820,000
Joint Western Pacific Railroad and State Highway Bridge	6,682,000	6,740,000
Joint Feather River Railway and County Road Bridge	2,850,000	5,020,000
Relocation of Power and Telephone Lines	1,348,000	1,348,000
Relocation of Forest Service Facilities	293,000	293,000
Subtotal	$313,539,000	$328,683,000
Contingencies	32,863,000	33,816,000
Engineering and Administration	30,251,000	31,514,000
Interest During Construction	42,008,000	40,371,000
Total Oroville Reservoir, Dams and Power Plant	$418,661,000	$434,384,000

DELTA CROSS CHANNEL

General Description

The Feather River natural flows, and subsequently the water released from Oroville Reservoir when built, would flow in the natural channels of the Feather and Sacramento Rivers to the Sacramento-San Joaquin Delta. Combined with water from other sources, principally the Sacramento River system, this water must be transported across the Delta to the intake of the Feather River Aqueduct. Under present conditions, water crossing the Delta must make its way through a complicated system of meandering and interconnected river channels and sloughs which are not satisfactory for delivering large quantities of water across the Delta. The Delta Cross Channel would provide an improved passageway.

This facility as proposed by the state would be an unlined channel approximately 44 miles long, constructed partly by excavating new channels and partly by dredging and improving existing channels.

Scope of Review and Methods Employed

In addition to the preliminary engineering and estimating data, developed by the State Engineer, further material was secured by Bechtel from the files of other governmental organizations concerned with the Delta problems. Another source of basic information is the report to the California State Legislature on the proposed barriers for San Francisco Bay System.[1] All these data were studied and reviewed.

The more important elements taken into account in this review are: (1) the proposed control structure at the Sacramento River intake; (2) railroad and highway bridges; (3) the San Joaquin River siphon crossing; (4) the cutting of new channels and the improvement by dredging of the existing channels; (5) drainage works and (6) the rearrangement of existing public and private utilities, and irrigation systems.

Comments

Because of the many complexities and uncertainties concerning both the physical features of the Delta Cross Channel and its relationship to other possible developments in the Delta region, it is not possible at this time to draw firm conclusions concerning specific physical features and costs of the proposed plan. The detailed review of the Biemond Plan, currently in progress by the Division of Water Resources by authority and appropriations of the 1955 Legislature, is essential to develop the basic information upon which definitive conclusions can be based. Therefore, the following comments should be considered as opinions and suggestions based upon over-all judgment.

It is concluded that a confined Delta Cross Channel is desirable and that its construction is engineeringly feasible. However, the presently undefined relationship of this proposed channel to various barrier and salinity control schemes, makes it impracticable to determine, at this time, whether the Delta Cross Channel, or what specific features thereof, should be considered as an integral part of the Feather River Project, for the purpose of determining the share of costs to be charged to the project.

The Feather River Project would not be the only beneficiary of a Delta Cross Channel. In whatever plan, or portion of a plan, that is constructed in the Delta, it is a reasonable premise that all the beneficiaries or responsible agencies should share equitably in the costs.

If a barrier plan, or some other salinity control plan, is completed prior to construction of the Delta Cross Channel, it should be expected that the cost to the Feather River Project would be less than if the salinity control plan were constructed concurrently or subsequently.

A determination should be made which would establish the benefits and responsibilities of the many interests involved in the Delta problems, relative to its physical and financial aspects.

When it appears that reasonable progress can be made toward clarifying the principal factors affecting the economic and financial status of the Delta Cross Channel, it would be desirable to acquire the necessary lands and rights of way as soon as possible. Continuing improvements and increase in land values will make acquisition more expensive as time passes.

ALAMEDA-SANTA CLARA-SAN BENITO BRANCH

General Description

This branch aqueduct would extend 108 miles from the headworks pumping plant on the main Feather River Aqueduct about two miles downstream on the canal from Pumping Plant No. I and would service areas in the Livermore and Santa Clara Valleys. The lift at the headworks pumping plant would be 498 feet, and the water would then flow by gravity, except that booster pumps would be required under certain conditions of storage at both Airpoint and Evergreen Reservoirs.

Preliminary plans for this branch aqueduct include 71 miles of open concrete-lined canal, three tunnels with an aggregate length of 2¼ miles, and 29½ miles of 90-inch to 72-inch diameter cut-and-cover precast reinforced concrete pressure pipeline.

Airpoint and Evergreen Dams would be earth-fill structures, providing storage of 23,000 and 32,500 acre-feet respectively.

Method and Scope of Bechtel Review

The State's reports, drawings, detailed cost estimates, and pertinent geological reports were studied,

[1] *Report to Water Project Authority of the State of California From Board of Consultants on Salinity Control Barriers in the San Francisco Bay Region*, Sacramento, California, March 12, 1955.

supplemented by a field reconnaissance. In addition, routing studies were made for both reservoirs.

Geology

The State made brief geologic examinations of both Airpoint and Evergeen Dam sites.[1] Both investigations were of a reconnaissance nature and no subsurface investigations were made.

Bechtel's examination of the Airpoint location confirmed the State Engineer's finding that this is a potential site for a dam and reservoir.

Of primary concern at the Evergreen Dam site is the presence of the potentially active Silver Creek Fault which is tributary to the main Hayward Fault. As recognized by the State, further geological investigations are necessary before final site selection and design.

No unusual adverse conditions were found to exist that would prevent construction of the aqueduct. However, a program of test boring will be required before final design is completed.

Aqueduct Location

The location selected by the State is generally satisfactory; however, an examination of topographic maps indicates that possible alternative schemes should be considered. For example, the Livermore Valley could be served by a smaller aqueduct over the same proposed route, with a separate small aqueduct leading from San Luis Reservoir via a pumping plant and a tunnel through Pacheco Pass to serve the Santa Clara Valley. This would make desirable reservoir storage available to provide more dependable service and would also result in smaller canals, pressure conduits and structures than now planned. A second alternate route should be considered with diversion of the total supply from San Luis Reservoir, with a small relift plant to make delivery to the Livermore Valley and contiguous service areas. These possible alternate routes have not been studied in detail by Bechtel.

Hydraulics and Structures

Analysis of the State's data indicates that the hydraulic characteristics for the different open canal sections, tunnel sections, and pressure pipelines are satisfactory. Structures proposed for the aqueduct, such as bridges, siphons, culverts, etc., are of designs which are in accord with good engineering practice and are adequate to deliver the estimated water demands.

[1] *Geological Report of Evergreen Dam Site on Silver Creek in Santa Clara County*, State of California, Division of Water Resources, December, 1950 (unpublished).
Geologic Report on Airpoint Site on Arroyo de los Coches, State of California, Division of Water Resources, January, 1951.
Airpoint Dam Site, State of California, Division of Water Resources, June, 1955 (unpublished memorandum).

Regulatory Reservoirs

The available data are insufficient for comprehensive analysis of the proposed Airpoint and Evergreen Dams, particularly as regards the characteristics of the dam foundations. However, the dam sections assumed are in accordance with accepted engineering practice. Flow routing studies, applicable to these reservoirs, indicate that their capacities are adequate for the regulation required on the lower reaches. A regulatory reservoir would be desirable to serve the Livermore Plain. Under the present plan this area is served by direct pumping from the Delta.

Estimate of Quantities

A review of the State's quantity estimates of the aqueduct reflected no significant differences except for the proposed tunnels.

Although the State Report mentions the need for booster pumps under certain operation conditions [2] at the regulating reservoirs, estimated costs for such pumps apparently were not included in their figures. This allowance has been made in the Bechtel estimate.

A review of the quantity estimates for the two dams confirmed that the State's allowance for these features is adequate.

A comparison of the differences in estimated quantities is given below:

	Unit	*State quantities*	*Bechtel quantities*
Structural steel (tunnels)	lb.	1,330,760	1,214,000
Miscellaneous metalwork (total)	lb.	145,830	--
Miscellaneous metalwork (tunnels only)	lb.	--	434,000
Drilling	lin. ft.	--	95,400
Grouting	sack	--	95,400
Booster pumps at Airpoint Reservoir	lump sum	--	$900,000
Booster pumps at Evergreen Reservoir	lump sum	--	$900,000

SAN LUIS DAM AND RESERVOIR

General Description

San Luis Dam and Reservoir are designed to serve as the principal storage and regulating basin on the Feather River Aqueduct south of Oroville Dam. The site for this dam and reservoir is on San Luis Creek about 12 miles west of the City of Los Banos, Merced County. The proposed zoned earth-fill type dam would be 18,700 feet long and 310 feet high above streambed, and would provide a storage capacity of 2,100,000 acre-feet if constructed to its full height. The principal appurtenant features include a low forebay with two separate pumping plants: Plant No. II-B pumping water directly into the reservoir and Plant No. II-A pumping water both into the reservoir and into

[2] *Office Report on Design and Cost Estimates of Feather River Project*, State of California, Division of Water Resources, Sacramento, California, June, 1955, p. 31.

a small afterbay at the head of the aqueduct leading south to Pumping Plant No. III. For Plant No. II-B there would be eight reinforced concrete conduits and for Plant No. II-A, four reinforced concrete conduits through the dam.

Two access towers and valve chambers would be located in the upstream section of the dam together with two trashrack and outlet structures.

Geology

Most of the geologic investigations, both areal and subsurface, of the San Luis site were performed by the Bureau of Reclamation. Reports on the geologic investigations, including geologic maps, logs of core holes, construction materials investigations and related data are included in the Bureau of Reclamation report.[1]

In reviewing the geologic conditions at the site, it became apparent that the Bureau of Reclamation investigations did not determine the depth of bedrock in the valley section south of San Luis Creek. Subsequent investigations by the Division of Water Resources were made in this area. In drill hole DWR 1 and 2, bedrock was encountered at relatively shallow depths, but in DWR 4, bedrock was encountered at 147 feet and DWR 3 was drilled to 138 feet without reaching bedrock. Overlying the bedrock in this deeper section is a zone of gravelly clay that has been reported as relatively impervious. This zone may prove to be sufficiently impervious for use as the base of the cutoff. Since core recovery in this zone was very poor, however, no tests are available on the material.

The Bureau of Reclamation investigations indicated that the outlet works conduits can be founded on rock; however, further exploratory drilling will be necessary before the conduits can be finally located.

Further investigations are needed to determine the type and depth of cutoff through the center portion of the dam, and to determine whether the gravelly clay layer overlying bedrock is adequate for a cutoff foundation. Further investigations on the abutments are required in areas where appurtenant structures are to be located.

Reservoir Capacity

The State proposes an ultimate capacity of 2.1 million acre-feet at San Luis Reservoir. On the basis of the state and Bureau of Reclamation studies, the capacity is the maximum logical physical development at the site, and the site itself is the best one available south of the Delta.

The Bechtel studies indicate that the full capacity of San Luis Reservoir is necessary to meet ultimate project demands. In the initial years of the project, only 1,000,000 acre-feet of capacity would be required for the presently estimated project demands. If project demands develop as fast as estimated by Bechtel, the total reservoir capacity at 2.1 million acre-feet will be required in about 15 years. The relative economics of constructing this dam in two stages is discussed subsequently.

Embankment

Only limited stability analyses of the main embankment were made by the State. These consisted of two modified Swedish slip-circles for the upstream face and two for the downstream face.

Independent stability analyses were made by Bechtel, using the procedure outlined by W. A. Brown of the State Engineer's Office but in the absence of soil test results, very conservative soil values were assumed.[2] In this analysis, assuming the reservoir level at elevation 415, approximately half full, and considering only gravity forces, the factor of safety for the upstream slope was found to be only 1.28, as compared to the accepted minimum value of 1.50. When an additional seismic force of 0.1 gravity was applied, the safety factor dropped to less than 1. Bechtel's analysis of the downstream slope indicates acceptable stability for steady seepage forces and for an additional seismic force of 0.1 gravity. However, since the San Andreas fault is only about 45 miles to the west, the assumed seismic force of 0.1 gravity may be exceeded and it is therefore concluded that the dam section proposed by the State is not adequate.

Another condition of utmost importance is the best use of local materials. At present, only about 10,000,000 cubic yards of pervious material have been located in the reservoir area immediately downstream from the dam and approximately 28,000,000 cubic yards of additional pervious material must therefore be transported for a distance of 10 miles. To partially overcome this deficiency of pervious material, Bechtel's analysis indicates that the downstream slope of the core could be flattened to 0.8 horizontal to 1.0 vertical, thereby decreasing the downstream pervious material by 3,546,000 cubic yards.

Bechtel analyses of the upstream section show that the following slopes will be required: a slope of 2:1 from elevation 560 to elevation 500; 3:1 from elevation 500 to elevation 450; 4:1 from elevation 450 to 400; and 5:1 from elevation 400 to the existing ground surface. This increased section compares closely with Bureau of Reclamations proposals and has a total embankment volume of about 76,000,000 cubic yards, as compared with the 68,000,000 cubic yards proposed by the State. If future soil tests show the material to be stronger than assumed, corresponding reduction in this dam section may be made.

The State proposes a first-stage low dam to be constructed to elevation 460. This section was reviewed

[1] *San Luis Division, Central Valley Project, Appendix E, Engineering Geology,* United States Bureau of Reclamation, Department of the Interior, November, 1953.

[2] *"Earth Dam Stability Analyses"* by W. A. Brown, April 18, 1952.

and was found to be unstable in the downstream section, principally because most of the downstream section is composed of low strength impervious material and because inadequate provision is made to handle seepage. Since the State's present design would require major revisions, it is believed that a design similar to that proposed by the Bureau of Reclamation would lend itself better to two-stage construction. If the dam is built in two stages, the source of impervious borrow material in the reservoir area would be unavailable for second-stage construction. This would necessitate the development of another source for about 16,000,000 cubic yards of impervious material.

Additional investigations are also needed to develop a source for as much pervious free-draining material as possible close to the dam site. It is of paramount importance that sufficient soil testing of embankment materials be performed to permit more accurate design of the embankment section.

Outlet Works

Water will be delivered to San Luis Reservoir by eight 11-foot diameter pump discharge lines from Pumping Plant II-B, and four lines of the same size from Plant II-A. The latter will also provide gravity flow from the reservoir to the aqueduct leading south to Pumping Plant III. All of these lines pass through the dam at about elevation 300, the eight lines from Plant II-B being located near the base of the left abutment and the four branch lines from Plant II-A on the right bank.[1]

As shown in the State's sketches,[2] the steel discharge lines housed in multi-barrel concrete pipe tunnels would extend approximately 900 feet to emergency butterfly valves in a concrete valve gallery under the crest of the first-stage dam. Both valve galleries would have vertical concrete hoist shafts to the surface. Separate concrete conduits extend from the valve chamber upstream approximately 450 feet to a trashrack-stoplog structure at the upstream toe of the dam. This structure provides ample trashrack area, but it would be possible to dewater the conduits upstream from the valve chamber only when the reservoir is below elevation 400 and it is believed that this condition will exist very infrequently under ultimate conditions. The State's proposed arrangement of the outlet works is functionally adequate and basically sound with this one exception.

In view of the considerable height of the embankment, the proximity to seismically active areas, and the importance of the dependent structures, a modification to permit inspection and maintenance of the full length of the outlet conduit at all times is believed justified. Accordingly, the Bechtel cost estimate includes extending the steel discharge pipes in multi-barrel concrete tunnels through the dam to the outlet structures. These structures would be full height (to elevation 560, ultimate) and would be of concrete column and girder construction, with a gantry crane and two tractor gates on each for emergency closure and dewatering of the conduits. The butterfly valves and chambers would thus be eliminated. For estimate purposes, a bridge designed for H-20 loading from the dam crest to each emergency gate structure is included.

Spillway

The drainage area tributary to the dam site was planimetered and found to be approximately 85 square miles. Based on a Creager coefficient of 60, the peak flood discharge inflow to the reservoir is approximately 800 cubic feet per square mile or 68,000 cubic feet per second.

If the storm had a total precipitation of 10 inches, of which six inches ran off as flood discharge, the volume of flood would be only about 27,000 acre-feet. This is essentially the same as the value determined by the U. S. Bureau of Reclamation and used by the State. This small flood volume indicates that there will be no flood flow over the spillway unless the reservoir is practically full at the start of the flood. Even if the flood occurs when the reservoir is at the normal maximum level, the total rise in water surface, with no reservoir outflow, would approximate only two or three feet. Thus, the spillway does not present a major design problem and the proposed spillway is judged to be adequate.

Quantities

A comparison of major quantities is as follows:

Item	*Unit*	*State quantities state section and structures*	*Bechtel quantities Bechtel section and structures*
Excavation	c. y.	5,352,400	5,500,000
Pervious embankment	c. y.	34,458,000	38,351,000
Impervious embankment	c. y.	32,038,000	35,608,000
Concrete	c. y.	119,578	184,600
Reinforced steel	lb.	25,385,400	20,347,000
Structural and miscellaneous steel	lb.	(included with reinf. steel)	3,385,000

Two-stage Construction

The state plan proposes construction of the dam in two stages. First-stage construction, from 1956 through 1959, would provide 1,000,000 acre-feet of storage with the crest at elevation 460. Second-stage construction, from 1967 through 1970, would increase the capacity to 2,100,000 acre-feet with a crest elevation of 560.

Two-stage construction of San Luis Dam would create certain engineering and construction problems such as the necessity of obtaining all second-stage

[1] *"Office Report on Design and Cost Estimates of Feather River Project Aqueduct,"* June, 1955, Appendix. State of California, Department of Public Works, Division of Water Resources. Drawing DC-1-103.

[2] *Calculation Book No. 20, "San Luis Reservoir Studies,"* Division of Water Resources, Section 3.

material from outside of the reservoir area and the additional mobilization and demobilization expense incurred.

Valid comparative cost estimates cannot be prepared pending the completion of materials investigations which will definitely locate adequate sources of pervious and impervious embankment materials and permit determination of the haul distances involved.

It is therefore recommended that the State's proposal for two-stage construction be re-evaluated with possible economic benefits from single-stage construction.

PUMPING PLANTS

The conveyance of Feather River Project water to service areas in the San Joaquin Valley and Southern California would require several pumping lifts at intervals along the aqueduct route. For any of the routes via Pastoria Creek, the State proposes seven pumping plants along the aqueduct up the west side of the San Joaquin Valley. The Coastal Route would utilize the first three of the above, plus six plants on the coastal portion. To serve the Livermore and Santa Clara Valleys, a relift plant near the aqueduct intake would be required.

Pumping costs would comprise a major portion of the project expenses. Approximately 20 percent of the debt service would pertain to the pumping plants and the annual power cost is estimated at $45,837,000 by 1991 for the State's High Line Route. The total power costs would be approximately 42.5 percent of the total annual expenses throughout the 71-year project payout period. The locations, capacities and operating characteristics of these plants are a vital consideration in planning the over-all development of the project. Data relative to the pumping plants as proposed by the State for the Pastoria Creek Routes are tabulated below:

DELTA TO PASTORIA CREEK

Plant No.	No. Units	Head ft.	Discharge		Installed hp.
			Unit cfs.	Plant cfs.	
I	8	235	1,375	11,000	344,000
Relift	[c]6	500	70	350	[c]30,000
II-A	4	215	1,000	4,000	120,000
	[a]4	318	1,000	4,000	160,000
		260	900		
				8,000	280,000
II-B	[a]8	318	1,000	8,000	320,000
		260	900		
III	8	155–165	750	6,000	124,000
IV	[c]8	311	700	5,000	[c]240,000
V	[b, c]8	314	700	5,000	240,000
		400	700		304,000
		714			[c]544,000
VI	[b, c]15	311	360	5,000	240,000
		795	360		600,000
		795	360		600,000
		1,901			[c]1,440,000

[a] Two-speed motors, [b] Multiple stage, [c] Includes spare unit.

Data relative to the pumping plants required for the Coastal Route would be the same as above as regards Pumping Plants No. I, II-A, and II-B and for the Alameda-San Benito-Santa Clara Diversion Relift Plant. The capacity of Pumping Plant No. III would be reduced and Pumping Plants No. IV, V, and VI listed above would be eliminated and the following plants added:

COASTAL ROUTE

Plant No.	No. Units	Head ft.	Discharge		Installed hp.
			Unit cfs.	Plant cfs.	
1	[a]11	136	340	3,400	[a]68,000
2	[a]11	135	340	3,400	[a]68,000
3	[a]11	213	340	3,400	[a]107,000
4	[a]11	413	340	3,400	[a]207,000
5	[a]11	459	300	3,000	[a]203,000
6	[a] 6	479	240	1,200	[a]92,000

[a] Includes spare unit.

Operating Characteristics

Pumping Plant No. I. The following comments apply to the ultimate development of the project. Pumping Plant No. I would draw water from the Delta up to the maximum extent of plant capability when this amount of water is available, and when it is required to supply the aqueduct and to replenish San Luis Reservoir. Water stored in San Luis Reservoir would be released to the aqueduct south of San Luis at times when the water being pumped from the Delta is insufficient which occur for the most part in the latter half of the year.

The exclusive use of off-peak electric energy at Pumping Plant No. I would result in a 46.5 percent reduction of plant pumping potential, as water flowing past the intake during on-peak hours could not be recovered to any significant extent during off-peak hours. As a consequence of the variation in water availability in the Delta, the State contemplates eventual continuous operation of the plant, pumping rates being adjusted to suit water availabilities. On-peak power demand charges would be incurred for the maximum annual load. Since Pumping Plant No. I flow rates would be primarily determined by water availability in the Delta, the 50 percent use factor (average flow divided by maximum plant capability) of the plant would be a reflection of variation in water availability only, and would have no direct bearing on off-peak pumping. The inverse relationship between Delta water flow and demand variations would determine the reservoir capacity required at San Luis.

Water availability in the Delta would vary monthly and annually. Examples of such variations on the basis of a computed duplication of historical flows, corrected for estimated future upstream diversions and storage releases, are shown on following page:

AVAILABILITY OF WATER IN DELTA FOR DIVERSION TO FEATHER RIVER PROJECT [1]

Month	Water year 1931 (1,000 a-f)	Water year 1935 (1,000 a-f)
January	508	1,371
February	357	820
March	300	1,273
April	4	3,141
May	26	1,588
June	51	1,186
July	226	229
August	276	233
September	258	220
October	206	276
November	219	250
December	1,160	367

[1] *"Program for Financing and Constructing the Feather River Project,"* State of California, Department of Public Works, Division of Water Resources, February, 1955, Appendix E-2.

During the inital years of project operation, Pumping Plant No. I is contemplated to be operated solely on off-peak power, since there would be sufficient water in the Delta for the early years of operation. With the ultimate capacity of Pumping Plant No. I installed by the year 1970, one-eighth of the plant capacity would be required for on-peak operation by 1976, building up to full-capacity on-peak operation by 1990. Oroville Reservoir regulated water releases would have little or no effect upon on-peak power requirements at Pumping Plant No. I, up to 1971. After that date, if the Feather River flow was not regulated by Oroville Reservoir, full-capacity on-peak operation would be required by 1980.

No spare pump would be required as pump maintenance could be conducted during the periods of low water in the Delta.

Pumping Plants No. II-A and II-B. Pumping Plants No. II-A and II-B of the State's plan would take suction from the San Luis Reservoir forebay. Each plant would consist of eight units of equal capacity. Each pump would have a separate penstock. At Plant No. II-A four units could discharge to either the reservoir or to the reservoir afterbay, and the remaining four units would discharge to the afterbay only. At Plant No. II-B all units would discharge to the reservoir only. The pumps that would discharge to the reservoir would be equipped with two-speed motors for the purpose of effecting power savings under the varying pumping head.

The forebay would have sufficient storage to permit a substantial amount of the necessary pumping during off-peak hours. The afterbay would not have sufficient storage, however, to regulate flow to the canal south of San Luis without use of San Luis Reservoir storage.

It is the intent of the State that Pumping Plants No. II-A and II-B would use off-peak power to the maximum practical extent. Such pumping would be limited to approximately 10 hours per day on week days and 20 hours per day on Saturdays and Sundays.

The amount of on-peak pumping required would depend upon inflow to the forebay. The maximum inflow to the forebay for the ultimate development would be 145,000 acre-feet per week. Under this condition four of the pumps would have to operate during on-peak hours and all pumps operated during off-peak hours to prevent an excessive buildup in the forebay. During the on-peak hours, pumping direct to the afterbay would be preferable. The annual on-peak demand would range between 84,200 and 92,000 kilowatts.

Fluctuations in monthly pumping rates at Plants No. II-A and II-B would parallel those for Pumping Plant No. I. Difference in seasonal requirements would permit scheduled maintenance of pumps without having to provide a spare unit.

San Luis Reservoir would be used to store water when the inflow to the forebay exceeds the demand south of San Luis. The stored water would then be released to the afterbay at times when demand south of San Luis exceeds the inflow to the forebay. In order to hold on-peak power demand charges to the minimum, water would be pumped to the reservoir during off-peak hours for release to the canal during on-peak hours. In order to eliminate the loss of head resulting from water released from the reservoir to the afterbay, the State plans to utilize the storage capacity in the canal below San Luis to the maximum practical extent when canal flow requirements are below capacity.

When the reservoir level drops to the afterbay level, reservoir storage being about 560,000 acre-feet, it will be necessary to drop water back from the reservoir to the forebay and then repump it to the afterbay. Should this condition occur during July or August when the full continuous capacity of the canal south of San Luis would be required, an on-peak demand of 160,000 kilowatts would be incurred. Seven units would be required to pump continuously to the afterbay. Reduced demand requirements at Pumping Plant No. I for these months permits the use of three or four pumps on-peak over the 84,200-kilowatt minimum demand for the normal requirements of Plants No. II-A and II-B without increasing on-peak demand requirements for the over-all project. Thus, the 84,200- to 92,000-kilowatt demand range specified above would satisfy both forebay and afterbay requirements.

The additional cost of energy at three mills per kilowatt-hour chargeable to the lost head when dropping water from the reservoir to the forebay, when the reservoir level is below the afterbay level, would be less than $200,000 for the most adverse year. During the 30-year period for which routings were computed by the State, the reservoir level fell below the afterbay level in six different years. In four of these years, the low reservoir level occurred in months when

demand south of San Luis was below maximum. The annual use factor of Pumping Plants No. II-A and II-B would range between 33.2 and 37.4 percent.

Pumping Plants Nos. III, IV, V, and VI. These four plants would be arranged in series along the aqueduct south of San Luis. The Buena Vista forebay just ahead of Plant No. III would permit intermittent off-peak operation of Plants No. III through VI, inclusive. The Quail Lake Afterbay at the discharge end of the tunnel beyond Plant No. VI would reregulate the intermittent inflow to continuous flow for delivery to the Southern California Service Area. The pumping plants and aqueduct between the Buena Vista Forebay and the Quail Lake Afterbay are intended to have sufficient capacity to transport the required water during off-peak hours, requiring about twice the capacity necessary for continuous flow.

The State provided no forebays or afterbays between Buena Vista and Quail Lake, and aqueduct itself would therefore be the only source of storage and surge capacity for regulating variations in flows along the canal between these points. Thus with a full canal, when Plant No. III starts pumping, Plants No. IV, V, and VI would have to be closely coordinated to pump at rates which would prevent an undue rise in water level in the canal at any point. Similarly, when pumping is stopped, it would have to be done in a delayed succession, downstream, to avoid flooding the canal as the total volume of water in a section between two plants levels out to a static water surface.

Thus, for every start-up, shutdown or major change in pumping rate, it would be necessary to operate both the canal and the four pumping plants in close coordination with the time lag sequence. The necessity for a full start-up and shutdown daily to take advantage of cheaper off-peak power would require many operations, and might affect the amount of power which could be used in off-peak hours.

Although the State has not located suitable sites for forebay reservoirs at the plants, it would be highly desirable to provide forebay capacity at each plant if this is found possible, after more exhaustive exploration. Otherwise, the canal banks should be raised to a level, or nearly level, grade, to provide additional storage and to prevent overtopping in the downstream portion of each reach when pumping is stopped.

It is anticipated that off-peak power would be available for pumping approximately 90 hours per week, on the average, for maximum plant requirements. Some off-peak electric energy may be available for longer than 90 hours, with duration of maximum off-peak demand then falling below the 90-hour average.

Monthly flow variations at Plant No. III would permit unit maintenance without a spare pump. The uniformity of monthly pumping requirements of Plants IV, V and VI would require a spare unit to be installed.

Economic Considerations of Plant Installed Capacities

Pumping Plant No. I. The capacity of Pumping Plant No. I is determined by the necessity for pumping the total annual amount of firm water supply required from the widely varying flows in the Delta, with reregulation of the pumped flows in San Luis Reservoir as necessary to suit water demands. In the State's studies covering a 31-year period, it was necessary to ration water one year considering the project in ultimate operation. Operation for five additional years was marginal, the project being able to just meet demand at full operation.

The pumping plant capacity is controlled by the ratio of the high winter flows to the small summer flows in the Delta. Proposed water releases from Oroville Reservoir, although scheduled principally to obtain the greatest power benefit, would increase summer water availability in the Delta. Minimum water releases for power generation during the three months of October, November and December would be approximately 42 percent of those required during July, August and September, the time when the demand for water would be the highest. Variations in Oroville Reservoir water releases for power generation would closely parallel those for the consolidated full deliveries to the service areas.

During water years 1931 through 1934 inclusive, the longest continuous adverse water period of the 31 years studied, a maximum total of approximately 774,000 acre-feet, or annual average of 194,000 acre-feet of all water released for power generation was not recovered at Pumping Plant No. I in the State's calculations. This amounts to only 4.8 percent of the total discharge of the pumping plant. Losses of such small magnitude would have little effect on capacity selection. Capacity reductions of Pumping Plant No. I and the Aqueduct to San Luis, which could be effected by complete use of the 1,577,000 acre-feet of dead storage at Oroville Reservoir, would be more than offset by losses in power revenues at Oroville Power Plant.

The on-peak kilowatt demand charge at Pumping Plant No. I is a major cost factor in the operation of the over-all project. A check analysis was made by Bechtel in which it was assumed that Pumping Plant No. I on-peak demand would be limited to five-eighths capacity. Full capacity would be used only during off-peak hours when sufficient water is available in the Delta. This resulted in a loss of only about 17 percent maximum pumping capability. Since the maximum capacity could be used only a few months of a year, the decrease in water deliveries for these months could be made up at times when the Delta

flow is low, provided that the low flow could be increased in proportion to the forementioned loss. Oroville Reservoir operation was therefore modified to accomplish this. This resulted in a loss of 30,000 kilowatts of dependable generating capability at Oroville in exchange for a reduction of 97,000 kilowatts on-peak demand at Pumping Plant No. I. This refinement is discussed in greater detail in a subsequent section.

It is therefore concluded that the capacity of Pumping Plant No. I as proposed by the State is reasonable and that pumping costs can be held to a minimum.

Pumping Plants Nos. II-A and II-B. The average annual costs of Pumping Plants No. II-A and II-B during the 40-year construction bond period would be approximately $9.10 per kilowatt of pumping capacity. Since this cost is appreciably below the annual demand charge for on-peak power, it would be reasonable to install additional pump capacity if on-peak demand could be reduced proportionately. Installing additional pump capacity would eliminate on-peak power required to maintain forebay level. Afterbay on-peak power requirements would not be affected by the installation of such additional pumping units.

In the check analysis previously discussed for Pumping Plant No. I, reducing its on-peak use to five-eighths of maximum capacity would eliminate the need for on-peak power at Plants Nos. II-A and II-B to maintain the forebay level. In order to eliminate on-peak power demand, as a result of the San Luis afterbay operation, approximately 15,400 acre-feet of additional live storage capacity would be required in this afterbay. In addition to the enlarged afterbay, four pumps located in Plant No. II-B would have to be located in Plant No. II-A. The relocated units would be provided with penstocks discharging to both the afterbay and reservoir. This plan is discussed in greater detail subsequently.

The capacity of Pumping Plants Nos. II-A and II-B as proposed by the State would be adequate for project requirements. Some modification in final design to the penstocks, afterbay and reservoir and distribution of the units would be desirable to reduce power costs.

Pumping Plants Nos. III, IV, V, and VI. The duration of time during which off-peak power would be available is a major factor in determining aqueduct and pumping plant operation between Buena Vista Forebay and Quail Lake Afterbay. In order to adequately check canal flows and to re-establish flows after periods of shutdown, off-peak operations confined to a maximum of 90 hours weekly would require capacities somewhat in excess of twice that for a continuous flow basis. It is anticipated, however, that off-peak power for demands less than maximum would be available for longer periods of time. Detailed studies of the power load distribution should be made in future years when preparing design specifications for these pumping plants and connecting aqueducts.

The unit sizes proposed by the State appear to be reasonable. However, considerable additional detailed studies should be made before the ultimate capacities and design features of the pumping plants are determined. Since these plants are not required for initial operations, there will be ample time for full investigation of all pertinent considerations in order to assure minimum pumping costs. These problems are practical of solution and the advances in pump engineering in the next 10 to 15 years are expected to materially simplify the problem.

Intermittent Operation of Pumping Plants

In the above discussion considerable reference has been made to the intermittent off-peak operation of the pumping plants. Numerous design problems would develop as a consequence particularly in Pumping Plants Nos. V and VI where it is proposed that multiple units be connected in series. The existence of such problems does not detract from the feasibility of the project. Pumping Plants Nos. I, II-A, and III would be installed in the initial construction and their intermittent operation on off-peak hours during this stage would be relatively simple. Coupled with anticipated engineering advances, the experience gained at these plants would provide valuable criteria for developing final designs for Plants Nos. V and VI.

The large size of the pumping units proposed for off-peak operation is not considered an insurmountable problem in view of the satisfactory performance of high head hydroelectric generating units larger than 60,000 kilowatts, which are started up and shut down daily for on-peak service and steam-electric generating units larger than 150,000 kilowatts using steam conditions of 1,450 psig and 1,000 degrees F. which are shut down nightly. Contemporary practice proves that problems arising from unit size are not without solution. Furthermore, when a demand for larger equipment develops, a substantial reduction in cost per unit of capacity usually follows.

The potential sale of pumps and motors in excess of 3,300,000 horsepower for the Feather River Project should stimulate keen design competition among the various interested manufacturers.

Pumping Plant Design Features

Basis of Designs Proposed by State.[1] All of the proposed pumping plants were originally sized by the State for continuous operation. Plant No. I was considered as supplementing the surplus capacity of the Tracy Pumping Plant and Delta-Mendota Canal. Pump and motor dimensions and estimated costs were obtained from manufacturers, and material quantities were estimated on this basis. When the

[1] *"Office Report on Design and Cost Estimates of Feather River Project,"* State of California, Division of Water Resources, Sacramento, California, June, 1955, Drawing Appendix.

capacity of Pumping Plant No. I was increased to 11,000 cfs. the operation was separated from the Central Valley Project, the off-peak pumping plan was adopted for the remainder of the plants, and the number and size of pumps were revised by the State to provide the necessary increase in capacity. Motor and pump sizes were redetermined for all plants and new drawings were made for Plants Nos. II-A, II-B, and VI. Pump and motor weights and prices were estimated from data previously developed for the continuous operation plan. Structural quantities for enlarged Plant No. I and the off-peak Pumping Plants Nos. II, IV, and V were determined by applying a factor to the information previously developed.

The State's presentation of the proposed Coastal Pumping Plants and Relift Plant consists essentially of stating the location, number and size of units, and penstock length for each plant. Costs were estimated on a unit price per cubic foot per second of capacity.

Structural Features. The plant sites are well located with respect to topography and service requirements. In the detailed layouts, attempts should be made to locate Plant No. II-A closer to the afterbay. Consolidation of Plants Nos. II-A and II-B should be investigated.

Site locations were appraised by Bechtel through the use of U. S. G. S. quadrangle maps and by aerial inspection. Soil classification logs contained in the U. S. B. R. San Luis Project Report were reviewed with respect to plant foundation requirements. Plant design was appraised for type, arrangement for operation and maintenance, and economy of structure. Structural adequacy was determined by review of State's drawings. The material quantities for the pumping plants were re-estimated using the State's procedures. Penstock quantities were recomputed for all plants.

The State has recommended semioutdoor structures for Plants Nos. I through V but consideration should be given to the use of an indoor structure when preparing final designs to determine the more economical plant. The pumping plant structures shown appear to be adequate for the loads involved and are sufficiently accurate for determination of preliminary estimating quantities.

The Bechtel estimates confirm the State's concrete quantities, but reveal differences on the items listed below:

Excavation—Bechtel quantities average 30 percent above the State's figures.

Reinforcing Steel—Bechtel quantities are about 17 percent less than the State's. Ratios used by Bechtel are 150 pounds per cubic yard for first-stage and 100 pounds per cubic yard for second-stage concrete rather than 165 pounds per cubic yard as used by the State.

Miscellaneous Steel—The total quantity of structural and miscellaneous steel estimated that would be required is about 20 percent less than the state estimate.

Forebay and Afterbay Dams—From quadrangle topography the state estimates appear to be minimum figures.

Pump Quantities—One spare unit of equal size to those proposed was added at Coastal Route Plants Nos. 1 through 6. Cost for the spare units was not included in the State's estimate.

Examination of results of foundation investigation at Plant No. I reveals conditions which make the use of piles questionable. Holes cc-11 and cc-13 show a limestone layer almost one foot thick near foundation elevation. This is underlain by material classified as fat clay with some interbedded silt. Drilling information and test data indicate that this latter material may be quite firm and fairly well indurated. Unconfirmed compressive strengths of the material from the above holes range from 17,000 to 100,000 pounds per square foot. Since the strata has a dip of from 35 to 45 degrees, additional drilling and testing is needed, especially to determine the possibility of differential settlement.

The use of hydraulically operated, interconnected butterfly valves for shutoff at Plants Nos. I through IV is appropriate. Current practice indicates that this type of valve could be used at Plant No. V as a substitute for the spherical or conical type valves proposed by the State Report since the latter would be higher in cost with no apparent advantage. Butterfly valves were used in the Bechtel estimate of Plant No. V.

In view of the controlled closure provided by the shutoff valves, a water hammer allowance of 15 percent, rather than 50 percent, as allowed by the State, is believed to be more realistic in penstock design. At Plants Nos. V and VI, the use of steel with a maximum allowable stress of 25,000 psi. is recommended in place of the 32,000-psi. valne proposed by the State.

The State did not provide sand traps ahead of the pump suctions. Such traps would be desirable in that they would minimize pump impeller wear. Basins should be provided which can be flushed or dredged during periods when the pumps are not in use.

Lack of foundation exploration and information concerning proposed sections for the forebay and afterbay dams at San Luis preclude a review of these embankments and emphasize the need for additional exploration at these sites. Bechtel recommends that a facility for dewatering the forebay be included in the project plans.

Equipment. The State proposes the use of a pump design requiring a low positive suction head in order to minimize underground construction work. The

pumps as proposed would be within the limits for safe specific speeds for the suction conditions selected.

The pumps for Plants No. I, II-A, II-B, III and IV would employ single-casing construction, of the single-volute design. Only the short diffuser would be of cast steel, the volute being built up of welded sections of fabricated steel supported by the diffuser ring. This results in a considerable saving. The casing, however, must be supported by setting in a reinforced concrete block.

Due to the low suction conditions for Plants No. V and VI the State proposes to use multi-casing pumps for those installations. Further investigation should be made of pump types to be used for these plants since single-casing pump units, of either single of multi-stage design are in operation or manufacture for heads above 4,000 feet. Operation of a single-casing pump would be less complicated than that of two or three pump units in series. Single units should also result in savings, both in equipment cost and less building volume. Efficiencies of 91 percent have been obtained by European manufacturers with 500-cfs., two-stage pumps operating against heads of more than 1,200 feet. While the development of high head pumps is fairly recent, progress could be expected in this field of design and manufacturing by the time Plants No. V and VI would approach the final design stage.

Since determination of the relative economies between single or multi-casing pumps would involve considerable design work and model testing of pumps, valves and penstocks, such tests should be initiated several years before the start of manufacturing.

While the pump units involved in the Feather River Project are uncommon in size and number, their design, construction, and satisfactory operation will be feasible.

FEATHER RIVER AQUEDUCT

Scope of Review and Methods Employed

The State considered a total of seven different routes for the Feather River Aqueduct, which are discussed herein. Due to the size of the project and limited time allotted for this review, it was necessary to use short-cut methods that would be fast and yet give results sufficiently accurate for a reasonable check of the State's proposals.

In addition to the air reconnaissance conducted over all proposed aqueduct routes, some of the more difficult areas were also inspected by automobile and on foot.

The State's supporting data were studied for general adequacy of the designs. Construction quantity estimates were made by Bechtel of all principal routes covered in the State's Report. In addition, consideration was given to modifications of the basic routes and cost estimates for these modifications were prepared.

The numbers, types, sizes, adequacy and quantity estimates of structures along the aqueduct line were checked by a study of profiles, quadrangle sheets, topography, and various maps pertaining to the areas in question. For a portion of the aqueduct line, the existing Delta-Mendota Canal also furnished a valuable guide as to the number and types of structures required.

The Bechtel review of the engineering feasibility of the various aqueduct proposals is presented under the following three general subjects:

Geology;

Basis of location and design;

Comparison of alternative routes.

Geology

Geologic investigations by the State of the various Feather River Project Aqueduct routes involved both detailed geologic explorations and reconnaissance. Detailed information regarding these investigations is included in reports by the Division of Water Resources entitled "Geologic Reconnaissance and Drilling Program for the Feather River Project Aqueduct —Italian Slough to Pastoria Creek" and "Geologic Investigations of Routes for the Feather River Project in Southern California."

It is to be noted, however, that the geologic investigations of the various routes which have been accomplished to date are, in most cases, of a preliminary nature and Bechtel concurs in the State's recommendation that comprehensive supplemental investigations be completed prior to final design of the Feather River Project.

In reviewing the geology along the aqueduct routes, all available data from the Division of Water Resources and from other agencies were carefully examined.

Italian Slough to Pastoria Creek. Geologic investigations by the State from Italian Slough to Pastoria Creek included both areal and subsurface investigations. Geologic strip maps were made by the State along the aqueduct route showing surface features. Subsurface investigations included 185 drill holes along the proposed route which were drilled and logged by the State. These holes and the test data obtained from samples recovered in this drilling program furnish an excellent guide for preliminary estimates and design. These data, however, are not sufficient to establish water table profiles with sufficient accuracy to determine the necessity of designing for uplift pressures due to high water table levels in some areas.

In certain locations along the route, expansive clays were encountered which upon hydration and dehydration could contribute to uplift on structures placed

upon them. Additional investigations will be necessary to accurately determine the extent of such deposits and also to determine the depth and extent of present and potential subsidence areas.

Routes Through the Tehachapi Mountains. The Tehachapi Mountains present some of the most difficult and complex terrain proposed to be crossed by the aqueduct route. The area is topographically the focal point to any route passing from the south San Joaquin Valley to the south coastal area.

Several alternate routes through the Tehachapi Mountains were located and investigated by the State. These routes are identified by the elevation at which their north portals are located. Three of these routes were found at relatively low elevations and four were found at higher elevations.

The low level routes investigated by the State are the 1500, 1700 and 1870. After some study it was found that Route 1500 passed through sedimentary formations suspected of having oil and gas deposits and was not considered further.

The high level routes investigated are the 3357, 3357 alternate, 3600 and 3000. The 3357 route is the original High Line Route. The 3357 alternate was proposed to avoid major faults and to locate the route almost entirely in crystalline rocks. The 3600 route also avoids faults and sedimentary rock. Route 3000 was investigated briefly and proposed as a low level route to Antelope Valley.

The State Geologic investigations along these routes, with the exception of the 3357 alternate and 3600 tunnels, consisted of geologic mapping in the immediate vicinity of the routes and a limited amount of core drilling. In addition to a 600-foot adit, six core holes were drilled on the 3357 route, and three holes were drilled on the 3600 route. Investigations were also made on the natural water springs in the area to estimate the quantity and temperature of water at tunnel elevation.

One of the most significant features in this area and one which makes tunneling particularly unpredictable is the existence of several large faults, including the San Andreas and Garlock Faults which are among the best defined in California and known to be active.

Other factors which will greatly influence tunneling conditions are the badly weathered and disintegrated rocks and the poorly indurated (hardened) sedimentary rocks. All of the tunnels, except the 3357 alternate and the 3600 tunnels, cross the major faults underground as well as crossing through badly weathered material and sedimentary rocks. To avoid these features, the State proposed and briefly investigated the 3357 alternate route. Based on incomplete geological data, the 3357 alternate route appears the best suited of the several routes proposed because it passes the major fault zones at ground surface level.

Preliminary geological investigations in this portion of the aqueduct route have been well executed and furnish an excellent guide for present studies as well as a basis for planning future work.

High Line Route. Geologic investigations by the State along the "High Line" route from Quail Lake to San Diego County consisted of a surface inspection of the more obvious geologic features. Tabulations showing rock types, overburden depths, and conditions affecting excavation costs are shown in the State's Reports. A reconnaissance trip was made by Bechtel to observe the rock types and general surface conditions as described in the State's Reports.

Coastal Route. The Coastal Route traverses in great part Monterey shales and cherts, serpentine formations and many major fault zones in the Temblor, Santa Lucia, San Rafael and Santa Ynez ranges. In addition, adverse conditions can be expected in the areas such as Sulphur Mountain, where occurrences of gas and oil are known. It is therefore considered probable that realignment and redesign of portions of the route will be necessary at the time that complete geological data becomes available.

Basis of Location and Design

Location. The preliminary location of the aqueduct line from the proposed intake at Italian Slough to the southern end of San Joaquin Valley is, in general, satisfactory, when considered from the following viewpoints:

Minimum disturbance to existing physical development.
Construction cost.
Maintenance.
Delivery to potential areas of water use.

South of Devils Den there are several possible alternates for an aqueduct line. This subject is reviewed elsewhere in this report.

Aqueduct Lining. The State's design of the aqueduct is based upon all concrete-lined canals and tunnels.[1]

On the basis of the data available, Bechtel concurs in the State's selection of this design.

Reinforcement in Concrete Lining. The State recommends use of unreinforced concrete lining in the Feather River Aqueduct. This is in accordance with the Bureau of Reclamation's experience in construction and operation of the Central Valley Project, as well as the experience of the Turlock Irrigation District, and the Gage and Riverside Canals, all in California.

Bechtel concurs in the selection of unreinforced concrete lining for the canals.

[1] *"Office Report on Design and Cost Estimates of Feather River Project Aqueduct,"* State of California, Division of Water Resources, Sacramento, California, June, 1955.

Typical Canal Sections. One important factor of the Feather River Aqueduct is the hydraulics of the proposed canal sections as related to over-all economy.

It is noted that the concrete lined sections proposed by the State [1] are designed for relatively low velocities (3.5 feet per second for Q equal to 2000 second feet to 4.41 feet per second for Q equal to 11,000 second feet). To check the economy of this feature, a cost analysis was made to determine the most economical section, considering both first costs and pumping costs. This study covered the reach of aqueduct between pumping Plants I and II-A and II-B. Bechtel estimates of unit costs were used, and the quantities were based on a theoretical balanced cut and fill section. A 72-year amortization period was used for the purpose of the study with interest at 2½ percent per annum. The results show that the typical sections as recommended by the State are reasonable. Due to the similarity of the design of all reaches of aqueduct, it is agreed that the recommendations by the State are acceptable for preparing preliminary estimates. However, in final design work this rather complex subject must be given careful study.

Underdrains. Seasonal fluctuations in the ground water table, together with potential changes due to canal seepage, make it difficult to determine the footage of underdrains which should be included in the Feather River Aqueduct; however, a greater amount of underdrainage than included by the State will probably be required. An estimated amount has been added to the Bechtel cost estimate for this purpose.

Siphons. Multiple-barrel monolithic box siphons are proposed by the State for aqueduct crossings of major streams and cross-drainage channels, major highway, railroads, and at selected locations where natural ground surface dips below normal aqueduct bottom grades. The hydraulic criteria used and calculations made by the State for determination of head losses through siphons were checked and found to be reasonable and in accordance with good engineering practice.

Concrete Bridges. Design criteria for proposed county road and state highway concrete bridges were reviewed and found to be adequate. The proposed designs will result in structures having utility value and useful life commensurate with similar type bridges being constructed elsewhere within the project area.

The 28-foot clear width roadway proposed for highway, while sufficient for purposes of preliminary estimates, will require some modifications in final design. On those reaches of open aqueduct sections that will cross subsidence areas it will be desirable to consider modifying concrete bridge final designs to provide "floating-type" decks of such nature that future raising would be facilitated.

Timber Bridges. The State's design criteria for proposed timber bridges for farm and other private roads crossing the aqueduct have been reviewed and were found to be satisfactory.

Cross-drainage Structures. Handling cross-drainage on those long reaches of the Feather River Aqueduct proposed for open-cut construction will present innumerable local and special problems which are not within the scope of either the State's preliminary report or this review. Consequently the following comment is concerned mainly with basic criteria used by the State for the typical designs included in the June, 1955, Appendix of their report.

The Burkli-Ziegler runoff formula used by the State yields rational results for the larger basins with relatively uniform shape and slope and the runoff confined to permanent channels. This formula is not as satisfactory, however, for the hundreds of smaller basins along the route. In those cases, the estimated runoff will require modification by application of judgment in consideration of individual local conditions and shall include consideration of what type of structure will be most economical, or if any structure should be provided.

For example, any overchute, regardless of runoff quantity, is relatively costly. Before a decision is made to provide an overchute, upstream diversion possibilities or increased size of other proposed cross-drainage structures should be investigated.

Similarly, it might be possible to eliminate some of the proposed cross-drainage culverts. For example, in the reach of aqueduct (Q equals 11,000 second-feet; 70-mile long) between Italian Slough and San Luis Forebay, 112 culverts are proposed by the State. This average of 1.6 culverts per mile appears high.

The above examples and some other features of design of cross-drainage structures indicate possible material savings. While it is not practicable within the scope of this review to determine the number, location and best design of the many individual structures, and the consequent possible cost saving, it is recommended that these features be given additional study in final design.

Turnout Structures. The typical turnout structure designs used by the State [2] are generally suitable for the purposes intended but it is recommended that consideration be given during final design to certain modifications that operating experience on other large canals have shown to be worthwhile. Turnout inlet structures should be equipped with trashracks having

[1] *"Office Report on Design and Cost Estimates of Feather River Project Aqueduct,"* State of California, Division of Water Resources, Sacramento, California, June, 1955.

[2] *"Office Report on Design and Cost Estimates of Feather River Project,"* State of California, Division of Water Resources, Sacramento, California, June, 1955, Appendix-Drawing DC-1-34.

sections of a size capable of easy removal for cleaning by no more than two men. Study should also be made of the advisability of providing certain turnouts with traveling moss screens.Each turnout structure from the main aqueduct, main laterals, and sublaterals, should be equipped with a standard flow measuring device.

Checks. The State's typical concrete check designs [1] are adequate in all respects. Between San Luis Creek and Pastoria Creek, an aqueduct distance of around 230 miles, the State proposes check installations approximately every 10 miles, which is considered adequate.

In final design, the possibility of combining check structures with aqueduct siphons should be considered. Radial gates at checks should be power-operated, and the design should include lighting for night operation.

Wasteways. It is important that adequate wasteways be provided. The wasteway structures and drainage channels leading from the aqueduct should be designed for the full capacity of the main aqueduct. Two exceptions to this are along the 70-mile reach between the intake and San Luis Dam, where it is proposed to utilize existing discharge channels (Westley and Newman) which are constructed for handling only wastage from the Delta-Mendota Canal. These two channels are not of sufficient capacity for handling the full capacity Feather River Aqueduct, and it would not appear practicable to reconstruct them for the required 11,000 second-foot capacity. Excess flows can pass downstream for handling at San Luis Forebay or it can be checked, as opportunity presents in the manner proposed in the State's Report.

The state proposal for utilization of Tulare Lake Basin for disposal of wastage from the Kettlemen City Wasteway, to be located near the Fresno-Kings county line, is questioned. Tulare Lake bottomlands are farmed intensively, and whatever opportunity may presently exist for utilization of that area as a reservoir for aqueduct wastages is being lost rapidly. Unseasonal flooding, and perhaps any flooding, undoubtedly would cause appreciable damage.

Attention is directed to specific mention in the State Report [2] that cost estimates do not include allowances for certain channel work in connection with necessary wasteway facilities along the aqueduct downstream from Kettlemen City Wasteway. While this is not susceptible of close evaluation, an allowance for this work has been included in the Bechtel estimates.

Additional Turnouts and Canal Checks. A study of U. S. Bureau of Reclamation experience on several long canals completed during the last decade reveals the desirability of including allowance in the original cost estimates for construction of additional turnouts and checks during the period when original construction is still active. Experience indicates that some water user organizations are loath to take positive action toward consummation of water-supply contracts until project construction is under way. Thus, the necessity for some turnouts and their appurtenant checks cannot be established in advance. An allowance for these items has been included in the Bechtel check estimates.

Irrigation and Utility Crossings. Other problems that will arise during the Feather River Aqueduct construction are those incident to disturbance, temporary handling, rerouting, reconstruction, of the facilities discussed in the following paragraphs.

Whether mainline railroad crossings over the aqueduct are made by bridges or over-siphons, service must be maintained during construction. This will require either temporary "shoofly" trackage, or a temporary trestle. Both methods are costly. If the line being crossed is a main track, companies are reluctant to issue "slow" orders over the construction site. Thus, first-grade construction for the temporary line is required. Signal, telegraph and telephone lines will also require temporary relocation.

There are 10 major railroad crossings along the High Line route from Italian Slough to Barrett Reservoir and directly identifiable costs included in the State estimate total $280,000. It is believed that this amount is not adequate for the work, and the Bechtel estimate provides a large allowance.

The State's proposal to have individual owners of disrupted irrigation systems do their own rehabilitation work (beyond aqueduct right-of-way limit) and be reimbursed under the land purchase (right-of-way) contracts, is basically sound.[3]

The state proposal to use bridges for carrying pipelines over the aqueduct is satisfactory. However, because of potential cost savings it is recommended that precast concrete pipe with rubber gasketed joints be used in lieu of monolithic concrete box or concrete-encased steel pipe for lines that must cross under the aqueduct.

The State's suggestion for placing power, phone, etc., circuits in ducts beneath the open aqueduct [4] is objectionable in locations where the ground might be wet for sustained periods or where there is danger of flooding. However, in other respects, the proposed plans for handling these utility crossings are satisfactory and the allowances included in the cost estimate are adequate.

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[1] *"Office Report on Design and Cost Estimates of Feather River Project,"* State of California, Division of Water Resources, Sacramento, California, June, 1955, Appendix-Drawings DC-1-24 and SA-1-2.

[2] *"Office Report on Design and Cost Estimates of Feather River Project,"* State of California, Division of Water Resources, Sacramento, California, June, 1955, pp. 42-43.

[3] *"Office Report on Design and Cost Estimates of Feather River Project,"* State of California, Division of Water Resources, Sacramento, California, June, 1955, p. 112.

[4] *"Program for Financing and Constructing the Feather River Project,"* State of California, Department of Public Works, Division of Water Resources, February, 1955, p. 59.

Operators of oil and gas pipelines are generally opposed to having the lines permanently siphoned under concrete-lined canals, since maintenance of the lines and future replacement by larger lines would be difficult. Owners prefer that the crossings be made above the canal and that existing pipeline gradients be maintained. The State's proposed cost allowances, however, seem adequate for permanent construction.

An additional allowance has been included in the Bechtel estimate for the temporary handling of these facilities during the construction period. Since oil and gas pipelines are usually under high pressure and cannot be removed from service for any substantial length of time, the temporary detour of these pipelines is quite expensive.

Fencing. The state cost estimates for aqueduct fencing ($1,500 per mile) indicate that only a four- or five-strand wire fence on wooden posts has been contemplated. The allowance should include a proportion of safety type (chain link) fencing along reaches in close proximity to urban areas and schools, pumping plants and other major structures. An allowance for chain-link fencing has therefore been included in the Bechtel estimate.

Safety Devices. Aqueduct construction should include safety devices, such as metal nets across siphon inlets and metal ladders at approximately 1,000-foot intervals staggered on canal side slopes. Since no identifiable provisions for these features is included in the State cost estimates, an allowance for such purposes has been added in the Bechtel estimate.

Land Acquisition—Access Roads—Landscaping—District and Field Office-Warehousing Facilities. The State's detailed cost estimate tabulations do not show identifiable items for land acquisition at pumping plant sites.[1] It is logical to assume that operation and maintenance headquarters for specific aqueduct reaches, storage depots, etc. will be located at pumping plant sites. Therefore, it would be advisable to acquire adequate extra space surrounding each plant to accommodate these facilities. It will also be necessary to provide access roads from existing public highways and there will be landscaping costs at selected works along the aqueduct line. Warehousing facilities will be needed at selected locations along the aqueduct for storage of supplies for operation and maintenance. It has been assumed that five such locations would be adequate.

The Bechtel cost estimate includes an amount for the above-listed items.

Communication System. Proper operation of the Feather River Aqueduct will entail integration of numerous routine and emergency actions taking place over a wide geographical area. A dependable communications system will be required for efficient operation and maintenance of the aqueduct.

No identifiable allowance for this is included in the State estimates. An estimated cost has therefore been included in the Bechtel estimate.

Tunnels. In reviewing tunnel designs, use was made of the State's proposed locations shown on U. S. G. S. quadrangle maps. Lengths, diameters and other data were also obtained from the State's computation books. In general, tunnel quantities estimated by Bechtel are somewhat higher than those used by the State.

The chief reason for the higher Bechtel figures on tunnel excavation and tunnel lining is that the sketches used in the State's computation books in most instances do not include overbreak allowance on the inverts equal to 50 percent of the lining thickness, whereas they do allow such overbreak on sides and arch. Overbreak on the invert would average about the same as on the sides and arch.

The concrete quantities shown in the State's computation books apparently include the volume shown on the drawings to be occupied by rock packing to the 50 percent overbreak line. This is a reasonable allowance since the probable cost of selecting or importing and placing acceptable rock for packing would approximate the cost of filling these spaces with concrete.

The State has provided an allowance in their estimates for pressure grouting where ground water under high pressure is anticipated. The State's figures are accepted as a reasonable estimate of grouting requirements for the aggregate length of tunnels.

The amount of the estimate of miscellaneous timber has been increased by Bechtel to allow a reasonable amount of blocking in addition to that shown in the sections of the appendix to the State's Report. Considerable blocking of this type will be required for which waste timber cannot be utilized and it therefore will become an item of cost. In addition an allowance has been made for a substantial amount of miscellaneous steel believed necessary for collar braces, tie rods, rib connectors, foot plates for steel supports, etc.

DISTRIBUTION OF PROJECT WATER

The sale of Feather River Project water is predicated upon the basis that delivery will be made only in wholesale quantities at canal side to distributing agencies, such as irrigation and water districts, and that no retail sales would be made to individual users.[2] The State assumed further, that these agen-

[1] *"Office Report on Design and Cost Estimates of Feather River Project,"* State of California, Division of Water Resources, Sacramento, California, June, 1955, Addendum.

[2] *"Program for Financing and Constructing the Feather River Project,"* State of California, Department of Public Works, Division of Water Resources, February, 1955, pp. 30-31, as amplified and clarified by discussions with personnel in the State Engineer's Office.

cies, either separately or jointly, will finance, construct, and operate whatever additional facilities are necessary for them to take and distribute the project water. From a practical standpoint, this presupposes that the necessary distributing agencies exist or will be formed, and that they will be able to finance and construct the necessary facilities and distribute and sell the water at a cost within the limits of the economic value of the water to the users.

Delivery of large quantities of water to the distributing agencies will require major modifications and additions to existing facilities and the construction of many new facilities. In some cases, substantial reservoirs will be required in or near the service areas to store and reregulate the delivered flow to the fluctuating demands of the users. Some of these reservoirs may require a substantial capacity to store off-season deliveries to meet peak-season demands and to provide a safety cushion to meet possible emergencies. The location of these reservoirs to take best advantage of favorable geographic, topographic and geologic conditions will not always coincide with the best position for subsequent distribution of the water. These conditions raise many widely differing and complex problems. Basically, the problems are quite different in the San Joaquin Valley than those encountered in Southern California.

In the San Joaquin Valley, the irrigable areas are relatively close to the proposed aqueduct line. This will entail construction of entirely new distribution systems. Due to the proximity of San Luis Reservoir, releases can be regulated to accommodate fluctuations in demand and to provide necessary protection against emergencies. It is thus concluded that neither terminal storage nor conveyance of project water from the aqueduct to points of delivery will present unusual problems in the San Joaquin Valley.

South of the Tehachapi Mountains a different condition exists. Large portions of the potential area to be served lie some distance from the State's proposed High Line Aqueduct Route. The area now contains many independent and widely different type distribution systems, and there are no storage facilities proposed as part of the Feather River Project sufficiently close to afford satisfactory distribution regulation. For these reasons, the State has given special consideration to possible methods by which the latter deliveries could be made.

The State Report [1] points out there are over one thousand organizations currently active in developing and distributing water in the 36,000 square mile coastal drainage area extending from the City of Santa Barbara southerly to the Mexican border. Both local and imported water supplies are being utilized. An extremely complex arrangement of water storage and distribution facilities is in operation, and the majority of the systems are characterized by their continued individual operation and expansion within purely local limits.

Excepting the few major systems, such as the Metropolitan Water District of Southern California and the Los Angeles Department of Water and Power, there is no material degree of physical and operational integration of the various existing independent systems.

Many alternative possibilities exist in the Southern California area for delivering Feather River Project water to existing independent distribution systems and combinations of systems. The State Report does not outline, as part of the Feather River Project, a definite physical system for regulating, conveying, and distributing project water from the main aqueduct. In view of the uncertainties involved, planning of such works at this stage would not be practicable. However, for illustrative purposes only, the State's Report [2] shows a possible scheme for location of such conveyance laterials, terminal reservoirs and distribution systems.

The actual system of works which would ultimately be constructed would not necessarily correspond to or resemble the illustrative system referred to. New systems and integration of existing systems will be brought into being gradually and in concert with the growth and need of the various service areas. In addition to supplying water to particular distribution systems, there would be opportunities to effect exchanges of water. On the High Line Route, for example, a connection might be made with the Los Angeles Aqueduct and an exchange be made for Owens Valley water which then could be diverted to portions of Antelope Valley. The San Diego service area might take additional supplies from the Colorado River Aqueduct that could be compensated for by Feather River Aqueduct water delivered to the Metropolitan Water District system in the San Fernando Valley.

In consideration of these various complex factors, possibilities, and uncertainties, Bechtel concurs in the State's proposals that:

> Feather River Project water should be delivered at the aqueduct side in wholesale quantities on a contract basis to properly constituted distribution agencies.
>
> The distribution agencies should finance, construct and operate the necessary facilities to receive and distribute the project water.
>
> The patterns of formation and integration of the distributing agencies to best serve the various areas will develop in due course as the needs arise, and

[1] *"Program for Financing and Constructing the Feather River Project,"* State of California, Department of Public Works, Division of Water Resources, February, 1955, p. 30.

[2] *"Program for Financing and Constructing the Feather River Project,"* State of California, Department of Public Works, Division of Water Resources, February, 1955, Plates II-A and II-B.

it would not be practicable or desirable to outline at this time any long-range detailed plan.

The costs of conveyance laterals from the main aqueduct, minor regulating reservoirs and distribution systems should not be included in the Feather River Project costs.

DISCUSSION OF PROPOSED ROUTES

All phases of the State's engineering investigations along the High Line Route, especially in the San Joaquin Valley, were more extensive than along the coastal and other proposed routes south of Pastoria Creek. For example, preliminary locations for the High Line were based on actual field surveys, whereas locations of coastal and other alternate routes were made on the basis of field reconnaissance and use of existing topographic maps. The design criteria and other general relationships determined from the more extensive study of the High Line Route were then used in studying alternate routes.

The following discussion brings together the results of the review of the individual features and compares them for appropriate reaches of the aqueduct and alternative routes.

Route No. 1—State High Line to Barrett Reservoir

The detailed preliminary designs of this route, construction schedules, and cost estimates, prepared by the State are reviewed by sections as determined by the type of terrain to be traversed or other characteristics in the opposite column.

Intake Channel—Italian Slough to Pumping Plant I. This unlined 2½-mile-long intake channel would convey water from the Delta Cross Channel to Pumping Plant No. I, located about three miles southeast of Byron, which would be the headworks for the Feather River Aqueduct. There would be no major construction problem in excavating the cut for this facility and the state cost estimate is believed adequate.

Pumping Plant No. I to San Luis Forebay. Pumping Plant No. I would ultimately lift 11,000 second-feet of water from approximately sea level to elevation 230 and discharge it into an open, concrete-lined canal section. The aqueduct would be approximately 25 feet higher than and west of the Delta-Mendota Canal at distances varying from a few hundred feet to about two miles, until San Luis Forebay is reached at 70 miles south of the aqueduct headworks. Delivery to this point would be by gravity flow in the canal. The recently constructed Delta-Mendota Canal facilitates evaluation of the adjacent reach of the Feather River Aqueduct, as many of the major construction problems to be encountered on the new canal would be similar in character to those which were met in the construction of the Delta-Mendota Canal. In general,

ROUTE NO. 1

COMPARATIVE SUMMARIES OF COST

STATE HIGH LINE ROUTE TO BARRETT RESERVOIR

	State	Bechtel
Oroville Reservoir, Dams and Power Plant, including Contingencies, Engineering and Administration and Interest during Construction	$418,661,000	$434,384,000
Feather River Project Aqueduct		
Delta Cross Channel	8,320,000	8,960,000
Fish Protective Works	2,400,000	2,400,000
Intake Channel		3,294,000
Pumping Plant No. 1	30,223,000	39,373,000
Aqueduct—Intake to San Luis Creek	52,507,000	43,771,000
San Luis Forebay	1,219,000	1,143,000
San Luis Dam and Reservoir	76,130,000	83,831,000
Pumping Plant No. II-A	30,486,000	34,824,000
Pumping Plant No. II-B	24,742,000	31,558,000
Aqueduct—San Luis Creek to Wheeler Ridge	106,681,000	97,290,000
Pumping Plant No. III	12,412,000	15,724,000
Pumping Plant No. IV	17,326,000	21,022,000
Pumping Plant No V	36,760,000	46,494,000
Pumping Plant No. VI	76,312,000	96,806,000
Buena Vista Forebay	1,452,000	2,724,000
Quail Lake Afterbay	400,000	443,000
Aqueduct—Wheeler Ridge to Cedar Springs	179,343,000	180,573,000
Aqueduct—Cedar Springs to Barrett Reservoir	190,894,000	223,392,000
Aqueduct—Alameda-Santa Clara-San Benito Branch	28,141,000	28,255,000
Relift Pumping Plant—Alameda-Santa Clara-San Benito Branch	3,122,000	3,936,000
Airpoint Dam and Reservoir	6,835,000	6,504,000
Evergreen Dam and Reservoir	5,492,000	5,584,000
District Offices, Communication Systems, Service Roads, etc.		948,000
Subtotal	$891,197,000	$978,849,000
Contingencies	135,526,000	161,916,000
Engineering and Administration	90,350,000	82,895,000
Interest during Construction*	57,174,000	65,440,000
Subtotal Feather River Project Aqueduct	$1,174,247,000	$1,289,100,000
Total cost	$1,592,908,000	$1,723,484,000

* Interest computed at 2.5 percent per annum.

the state cost estimates and preliminary design for this reach of aqueduct are adequate with the exception of small differences in quantities found in Bechtel's review.

San Luis Forebay to Fresno-Kings County Line. The aqueduct capacity is reduced from 11,000 second-feet to 7,000 second-feet beyond San Luis and Pumping Plants II-A and II-B.

In reviewing this 95-mile reach of aqueduct use was made of experience gained by others in design, construction and operation of existing canals and similar structures in the adjoining areas. It is concluded that the State's estimate of canal earthwork, trimming and lining quantities are reasonable. Although the sizes and types of structures in the reach are satisfactory, the Bechtel estimate of concrete quantities is approximately 10,000 cubic yards less than that reported by the State with a corresponding difference in the reinforcing steel quantities. The review indicates that

some additional features, as previously discussed, should be added.

Fresno-Kings County Line to Buena Vista Hills. At the Fresno-Kings County line the aqueduct capacity is reduced from 7,000 to 4,000 second-feet, due to the diversion of 3,000 second-feet to Fresno and Kings Counties. This amount of water would not be diverted at a single point but is the estimated cumulative total of several smaller diversions of undetermined quantity and location. However, the total amount is equal to nearly one-half the capacity of the upstream canal section and nearly equal to the remaining capacity downstream. While it is physically possible to operate the aqueduct in this manner, some problems of coordination of the widely varying water requirements with releases from San Luis Reservoir will result. This situation would be greatly improved if regulatory storage could be provided along the canal at convenient locations, or as terminal storage at the points of greatest diversion. The Kettlemen City wasteway, which would discharge excess water into the Tulare Lake Basin, would also be located near this point. The state and Bechtel estimates both include a lump sum for this facility. This wasteway is approximately seven miles below the point where the State proposes to reduce the canal section and Bechtel has therefore included an allowance for maintaining an aqueduct capacity of 7,000 second-feet to that location. While the construction of this wasteway is physically feasible, the prudence of wasting water into the Tulare Lake Basin is doubted for reasons previously discussed.

Bechtel quantities in this section are approximately 11 percent higher for canal excavation than the State's, primarily due to the increase discussed in the preceding paragraph.

Buena Vista Hills to Wheeler Ridge. The State estimate for the forebay at Pumping Plant III is in the form of a lump sum. In order to check quantities for this feature, Bechtel located a dike to provide a total storage of 25,000 acre-feet. This would permit approximately two days uninterrupted flow in case of an emergency shutdown of Pumping Plant III.

In the state plan, aqueduct capacity is increased downstream from Pumping Plant III from 4,000 to 6,000 second-feet to permit off-peak operation at Pumping Plant III.

Bechtel estimated canal excavation quantities for this reach are approximately 25 percent less than the State's, but computed concrete quantities are approximately 15 percent over the State's. There is general agreement on quantities for individual structures but differences exist on accumulated totals.

Wheeler Ridge to Pastoria Creek. Aqueduct capacities are reduced from 6,000 to 5,000 second-feet downstream from Pumping Plant IV. Wasteways are located upstream from both Pumping Plants IV and V. These wasteways, converging into a common channel which leads to a proposed holding reservoir near Kern Island, will require further detailed consideration. The State's estimates of costs and capacities for Kern Island and Pastoria Creek Wasteways are considered reasonable although Bechtel estimated quantities for canal earthwork and concrete lining are less than the State's by 32 percent and 20 percent respectively.

As previously discussed, additional quantities for measuring devices and safety features were added to this reach of aqueduct.

Pastorial Creek to Quail Lake. From the siphon breaker at the discharge of Pumping Plant VI to Quail Lake Afterbay, the aqueduct consists of approximately 10¼ miles of 26.7-foot-diameter tunnel at elevation 3,357 with a capacity of 5,000 second-feet.

This tunnel, as presently located, will pass through some of the most complex and difficult portions of the Tehachapi Mountains. However, brief geological examinations by the State and subsequently by Bechtel indicate that an alternative location further to the east would avoid most of the serious difficulties and would result in less costly construction and more reliable operation. It is therefore recommended that this alternate location be given further consideration if the High Line Route is adopted.

The cost of this tunnel is estimated at approximately $90,000,000. If afterbay facilities were available at Pumping Plant VI close to the entrance to the tunnel, the tunnel could be driven at about 20-foot diameter for a capacity of about 2,500 second-feet. This would result in a savings of some $20,000,000 to $30,000,000 for the tunnel. It is recommended that further investigations be made to locate a suitable storage site between Pumping Plant VI and the tunnel.

A comparison of estimated quantities by the State and by Bechtel check as closely as is reasonable to expect.

Quail Lake to Cedar Springs. This portion of the aqueduct, located along the southerly edge of the Antelope Valley, is of three capacities; 2,300 second-feet at the upper end, an intermediate capacity of 2,000 second-feet, and a short reach of 1,200 second-feet capacity. It is proposed to divert 800 second-feet at Oso Canyon for use in Antelope Valley, 200 second-feet at Elizabeth Lake Canyon and 300 second-feet at San Francisquito Canyon.

There are approximately 4.5 miles of 20-foot diameter tunnel with a capacity of 2,300 second-feet, and 0.33 mile of 14-foot diameter tunnel with a capacity of 1,200 second-feet. As discussed elsewhere in this report, further geological investigations are necessary before making final determinations on the loca-

tions and structural design of this section of the aqueduct.

Bechtel's check estimate is based upon excavation quantities of the several classifications, as determined by field examination. Reasons for differences in estimated tunnel quantities have been previously discussed.

Cedar Springs to Barrett Reservoir. In this 139-mile reach of aqueduct there are approximately 91 miles of tunnels consisting of the following:

Length (miles)	*Diameter (ft.)*	*Capacity (cfs.)*
20.0	14.0	1200
9.5	13.0	900
10.0	12.0	800
5.5	10.0	500
18.0	9.5	500
11.5	8.0	300
16.5	7.0	200
Total: 91.0		

There are no substantial differences between the State's and Bechtel's estimates for open channel construction quantities and the reasons for tunnel quantity differences have been previously discussed.

Further geological investigation is necessary for final design and location of the aqueduct through this region. Experiences gained in the design and construction of the San Diego and Colorado River aqueducts in this area will prove valuable in final planning.

Comparison of Cost Estimates. A comparison of the respective cost estimates for the State's High Line, Route 1, including Oroville Reservoir, dams and power plant is presented on the following page.

Route No. 2—State High Line to San Bernardino and the Devil Canyon Power Drop

General Description. This route is identical to the Basic High Line from the Delta to the Cedar Springs Forebay but beyond this point a modified route was developed by the State. The following discussion pertains only to that modified portion.

Under this plan, a continous supply of 2,000 second-feet would be delivered by the aqueduct into Cedar Springs Reservoir. This reservoir, which would have a total capacity of 14,170 acre-feet, with 9,420 acre-feet of usable storage, would regulate the uniform inflow into power draft peaks of 4,480 second-feet. The power drafts would be conveyed by $4\frac{3}{4}$ miles of 22-foot diameter tunnel and eight penstocks to the Devil Canyon Power Plant, which would consist of eight 56,000-kw. units operating under a maximum head of 1,570 feet.

During peak power generation, 2,000 second-feet of water would be conveyed from the tailrace pool by pipe line to a stilling basin and division pool, where 500 second-feet could be diverted to Morris Reservoir and 1,500 second-feet to Lake Mathews. The remaining 2,480 second-feet would flow into an afterbay reregulating reservoir having a capacity of 14,400 acre-feet. During periods when no power is generated, 2,000 second-feet would be drawn from the afterbay to maintain the continuous supply to Morris Reservoir and Lake Mathews.

ROUTE NO. 2

COMPARATIVE SUMMARIES OF COST

STATE HIGH LINE TO SAN BERNARDINO AND DEVIL CANYON POWER DROP

	State	Bechtel
Oroville Reservoir, Dams and Power Plant, including Contingencies, Engineering and Administration and Interest during Construction	**$418,661,000**	**$434,384,000**
Feather River Project Aqueduct and Devil Canyon Power Development		
Delta Cross Channel	8,320,000	8,960,000
Fish Protective Works	2,400,000	2,400,000
Intake Channel		3,294,000
Pumping Plant No. I	30,223,000	39,373,000
Aqueduct—Intake to San Luis Creek	52,507,000	43,771,000
San Luis Forebay	1,219,000	1,143,000
San Luis Dam and Reservoir	76,130,000	83,831,000
Pumping Plant No. II-A	30,486,000	34,824,000
Pumping Plant No. II-B	24,742,000	31,558,000
Aqueduct—San Luis Creek to Wheeler Ridge	106,681,000	97,290,000
Pumping Plant No. III	12,412,000	15,724,000
Pumping Plant No. IV	17,326,000	21,022,000
Pumping Plant No. V	36,760,000	46,494,000
Pumping Plant No. VI	76,312,000	96,806,000
Buena Vista Forebay	1,452,000	2,724,000
Quail Lake Afterbay	400,000	443,000
Aqueduct—Wheeler Ridge to Cedar Spring	179,343,000	180,573,000
Cedar Springs Forebay	3,782,000	4,206,000
Aqueduct—Cedar Springs to Devil Canyon	24,984,000	30,896,000
Devil Canyon Power Plant	66,185,000	65,826,000
San Bernardino Afterbay, Dam and Reregulation System	21,275,000	29,525,000
Aqueduct—Alameda-Santa Clara-San Benito Branch	28,141,000	28,255,000
Relift Pumping Plant—Alameda-Santa Clara-San Benito Branch	3,122,000	3,936,000
Airpoint Dam and Reservoir	6,835,000	6,504,000
Evergreen Dam and Reservoir	5,492,000	5,584,000
District Offices, Communication Systems, Service Roads, etc.		948,000
Subtotal	$816,529,000	$885,910,000
Contingencies	124,244,000	140,172,000
Engineering and Administration	82,964,000	81,406,000
Interest During Construction	48,749,000	55,220,000
Subtotal Feather River Project Aqueduct and Devil Canyon Power Development	$1,072,486,000	$1,162,708,000
Total cost	$1,491,147,000	$1,597,092,000

Designs and Estimated Quantities. Bechtel's review of the proposed arrangement and designs described above revealed no significant objection to the proposed state plan, which is reasonable and in accord with good engineering practice throughout. However, some omissions and differences in estimated quantities were disclosed.

No definite plans were outlined by the State for conveying the water to Morris Reservoir and Lake

Mathews or other terminal reservoirs. The route to Morris Reservoir is through thickly populated areas and the route to Lake Mathews traverses some rather rough and difficult terrain. Bechtel's estimate of these systems indicates a total cost of approximately $50,000,000.

In some instances, such as for the powerhouse, where the State's estimate included only lump sum costs, the Bechtel estimate was developed in more detail.

Route No. 3—State High Line to Quail Lake and Castaic Creek Power Drop

General Description. This proposed state modification is identical to the basic High Line Route from the Delta to Quail Lake Forebay but from that point all water would flow, mostly by tunnel, 10.5 miles to Ridge Basin Powerhouse and 7.5 miles further to Castaic Creek Powerhouse at Castaic Creek Reservoir. The following discussion pertains only to that portion of this route which is south of Quail Lake.

ROUTE NO. 3

COMPARATIVE SUMMARIES OF COST

STATE HIGH LINE TO QUAIL LAKE AND CASTAIC POWER DROP

	State	Bechtel
Oroville Reservoir, Dams and Power Plant, including Contingencies, Engineering and Administration and Interest during Construction	**$418,661,000**	**$434,384,000**
Feather River Project Aqueduct and Castaic Creek Power Development		
Delta Cross Channel	8,320,000	8,960,000
Fish Protective Works	2,400,000	2,400,000
Intake Channel		3,294,000
Pumping Plant No. I	30,223,000	39,373,000
Aqueduct—Intake to San Luis Creek	52,507,000	43,771,000
San Luis Forebay	1,219,000	1,143,000
San Luis Dam and Reservoir	76,130,000	83,831,000
Pumping Plant No. II-A	30,486,000	34,824,000
Pumping Plant No. II-B	24,742,000	31,558,000
Aqueduct—San Luis Creek to Wheeler Ridge	106,681,000	97,290,000
Pumping Plant No. III	12,412,000	15,724,000
Pumping Plant No. IV	17,326,000	21,022,000
Pumping Plant No. V	36,760,000	46,494,000
Pumping Plant No. VI	76,312,000	96,806,000
Buena Vista Forebay	1,452,000	2,724,000
Aqueduct—Wheeler Ridge to Quail Lake	70,876,000	78,762,000
Quail Lake Forebay	3,626,000	8,882,000
Aqueduct—Quail Lake to Liebre Gulch	31,088,000	47,837,000
Liebre Gulch Power Plant	19,956,000	27,166,000
Liebre Gulch Afterbay	1,107,000	2,465,000
Aqueduct—Liebra Gulch to Castaic Creek	48,510,000	28,378,000
Castaic Power Plant	32,190,000	40,581,000
Castaic Creek Dam and Reservoir	12,171,000	14,934,000
Aqueduct—Alameda-Santa Clara-San Benito Branch	28,141,000	28,255,000
Relift Pumping Plant—Alameda-Santa Clara-San Benito Branch	3,122,000	3,936,000
Airpoint Dam and Reservoir	6,835,000	6,504,000
Evergreen Dam and Reservoir	5,492,000	5,584,000
District Offices, Communication Systems, Service Roads, etc.		948,000
Subtotal	$740,084,000	$823,446,000
Contingencies	119,344,000	129,456,000
Engineering and Administration	74,008,000	76,504,000
Interest During Construction	43,425,000	50,898,000
Subtotal Feather River Project Aqueduct and Castaic Creek Power Development	$976,861,000	$1,080,304,000
Total cost	$1,395,522,000	$1,514,688,000

Under this modification, the equivalent of a continuous supply of 2,500 second-feet would be supplied to Quail Lake Forebay by the Pastoria Creek pumps on an off-peak schedule. Quail Lake Forebay reservoir would provide 16,740 acre-feet of usable storage for reregulation of this inflow, principally for on-peak power drafts. A continuous flow would be released from the reservoir for distribution throughout the Mojave Desert. Flows to Ridge Basin power plant would cross the San Andreas Rift Zone in an open canal approximately two miles long and then via three 22-foot diameter tunnels and three double barrel 16-foot diameter siphons to the head of the penstocks for Ridge Basin power plant. This plant would have four 52,500 kw. units with a total dependable capacity of 209,800 kw. under a gross head of 738 feet, and would discharge directly into Ridge Basin Reservoir. The reservoir would have a total storage of 9,400 acre-feet, of which 3,400 acre-feet is for reregulation and 6,000 acre-feet for emergency use. Maximum water surface elevation would be 2,500 feet. The spillway would have a capacity of 4,480 second-feet, which is equal to the maximum inflow.

From Ridge Basin Reservoir, to Castaic Creek power plant the route consists of approximately 6.2 miles of tunnel and 0.3 miles of siphon. Castaic Creek power plant would have four penstocks over 3,000 feet long, four 76,700 kw. units with a dependable capacity of 306,500 kw. under a maximum head of 1,078 feet, and would discharge by means of a tail channel into Castaic Creek Reservoir. Under this state scheme Castaic Creek Reservoir would provide 9,420 acre-feet for reregulation but additional capacity could be developed for seasonal or long-time carry-over.

Design and Estimated Quantities. From an engineering viewpoint, the Castaic Creek Power Development scheme, as a terminus for the Basic High Line Route has important advantages not offered by the other state routes.

Since this route crosses the Garlock and San Andreas faults on the surface, the hazard of extended periods of interrupted flow, due to seismic activity, is greatly reduced. This proposal has the additional advantages of terminating at a site that is capable of being developed into a large capacity reservoir, providing reregulatory storage, and meeting additional power generation requirements.

In some items such as the powerhouses, where the State used lump sum costs, Bechtel's estimate is more comprehensive. Some omissions and differences in estimated quantities were also noted in Bechtel's review of the State's estimate for this route.

Route No. 4—State High Line to Devils Den Coastal Line to Castaic Creek Reservoir—Branch Extension to Wheeler Ridge

General Description. This route and all features thereof are the same as the High Line Route from the Delta to Devils Den. From this point the State recommended a 2,300 second-foot capacity branch extension to Wheeler Ridge.

The Coastal Line would depart from the High Line Route at Devils Den. Capacity of the aqueduct would be 1,700 second-feet from Devils Den to Ventura and 1,500 second-feet from Ventura to Castaic Reservoir. This route proceeds north across Halsey Canyon near Del Valle and up Castaic Valley to the proposed Castaic Reservoir at the junction of Castaic and Elizabeth Lake Canyons. The six Coastal Line pumping plants on this route lift the water a total of 1,457 feet. The locations of the first four pumping plants are the same as those on the longer Coast Route (Route 5). Pumping Plant No. 5 would be located immediately south of State Highway 126, and Pumping Plant No. 6 would be situated at the toe of the proposed Castaic Dam.

Design and Estimated Quantities. Bechtel's review was based on a comparison of this route with the longer route subsequently described. The state proposal does not include plans or costs for conveying water from Castaic Creek Reservoir to distribution systems of Southern California service areas.

Route No. 5—State High Line to Devils Den—Coastal Line to San Jacinto Tunnel—Branch Extension to Wheeler Ridge

General Description. This route, as proposed by the State, would be identical to Route 4, except that from the South Fork of the Santa Clara River the capacity of the aqueduct would be 1,200 second-feet to Mint Canyon. From that point to the west portal of the San Jacinto Tunnel, the Coastal Line and the Long Tunnel Line, Route 7, are identical. A capacity of 1,200 second-feet is also provided to a point southeast of San Bernardino, where it is again reduced to

ROUTE NO. 4

COMPARATIVE SUMMARIES OF COST

STATE HIGH LINE TO DEVILS DEN—COASTAL LINE TO CASTAIC CREEK

	State	Bechtel
Oroville Reservoir, Dams and Power Plant, including Contingencies, Engineering and Administration and Interest during Construction	**$418,661,000**	**$434,384,000**
Feather River Project Aqueduct		
Delta Cross Channel	$8,320,000	$8,960,000
Fish Protective Works	2,400,000	2,400,000
Intake Channel		3,294,000
Pumping Plant No. I	30,223,000	39,373,000
Aqueduct—Intake to San Luis Creek	52,507,000	43,771,000
San Luis Forebay	1,219,000	1,143,000
San Luis Dam and Reservoir	76,130,000	83,831,000
Pumping Plant No. II-A	30,486,000	34,824,000
Pumping Plant No. II-B	24,742,000	31,558,000
Aqueduct—San Luis Creek to Wheeler Ridge	103,588,000	86,177,000
Pumping Plant No. III	6,580,000	3,931,000
Coastal Line Aqueduct—Devils Den to Castaic Creek	375,362,000	409,300,000
Coastal Line Pumping Plants	73,627,000	56,963,000
Castaic Creek Dam and Reservoir	12,171,000	15,594,000
Aqueduct—Alameda-Santa Clara-San Benito Branch	28,141,000	28,255,000
Relift Pumping Plant—Alameda-Santa Clara-San Benito Branch	3,122,000	3,936,000
Airport Dam and Reservoir	6,835,000	6,504,000
Evergreen Dam and Reservoir	5,492,000	5,584,000
District Offices, Communication Systems, Service Roads, etc.		948,000
Forebays and Afterbays for Coastal Pumping Plants		24,000,000
Subtotal	$840,945,000	$890,346,000
Contingencies	149,331,000	146,069,000
Engineering and Administration	84,080,000	74,808,000
Interest During Construction	56,971,000	61,368,000
Subtotal Feather River Project Aqueduct	$1,131,327,000	$1,172,591,000
Total cost	$1,549,988,000	$1,606,975,000

ROUTE NO. 5

COMPARATIVE SUMMARIES OF COST

STATE HIGH LINE TO DEVILS DEN—COASTAL LINE TO SAN JACINTO

	State	Bechtel
Oroville Reservoir, Dams and Power Plant, including Contingencies, Engineering and Administration and Interest during Construction	**$418,661,000**	**$434,384,000**
Feather River Project Aqueduct		
Delta Cross Channel	$8,320,000	$8,960,000
Fish Protective Works	2,400,000	2,400,000
Intake Channel		3,294,000
Pumping Plant No. I	30,223,000	39,373,000
Aqueduct—Intake to San Luis Creek	52,507,000	43,771,000
San Luis Forebay	1,219,000	1,143,000
San Luis Dam and Reservoir	76,130,000	83,831,000
Pumping Plant No. II-A	30,486,000	34,824,000
Pumping Plant No. II-B	24,742,000	31,558,000
Aqueduct—San Luis Creek to Wheeler Ridge	103,588,000	86,177,000
Pumping Plant No. III	6,580,000	3,931,000
Coastal Line Aqueduct—Devils Den to San Jacinto	585,556,000	641,591,000
Coastal Line Pumping Plants	88,908,000	71,136,000
Aqueduct—Alameda-Santa Clara-San Benito Branch	28,141,000	28,255,000
Relift Pumping Plant—Alameda-Santa Clara-San Benito Branch	3,122,000	3,936,000
Airport Dam and Reservoir	6,835,000	6,504,000
Evergreen Dam and Reservoir	5,492,000	5,584,000
District Offices, Communication Systems, Service Roads, etc.		948,000
Forebays and Afterbays for Coastal Pumping Plants		24,000,000
Subtotal	$1,054,249,000	$1,121,216,000
Contingencies	191,861,000	189,734,000
Engineering and Administration	105,425,000	88,861,000
Interest During Construction	67,371,000	78,545,000
Subtotal Feather River Project Aqueduct	$1,418,906,000	$1,478,356,000
Total cost	$1,837,567,000	$1,912,740,000

800 second-feet. This capacity continues to the west portal of the San Jacinto Tunnel.

The Coastal Line aqueduct involves some 70 miles of 17-foot diameter tunnels. Six pumping plants to lift the water a total of 1,835 feet would be located between Devils Den and the Mint Canyon junction with the Long Tunnel Route.

The first tunnel, 4½ miles long, passes through the Temblor Range with a cover of 800 to 1,000 feet, crossing the San Andreas fault about at right angles. It is in Monterey shale and chert, and difficulty in tunnel construction may be expected. The next tunnels between Mile 416 and Mile 455 will encounter Monterey shale and serpentine near Santa Margarita and San Luis Obispo where considerable heavy and squeezing ground was encountered during the construction of tunnels for the Southern Pacific Railroad. There are six tunnels in this 39-mile reach, aggregating a total length of about 29 miles, with lengths ranging from about 7,000 to 38,000 feet. Difficult tunnel construction must be anticipated, since this route lies generally within the Monterey or allied formations, passes within 40 miles of the San Andreas fault, and is crossed by several fairly well-defined fault zones. At Mile 490 is a five-mile tunnel in the San Rafael Range with a similar characteristics. At Mile 508 the line crosses the Santa Inez River and proceeds eastward for 10 miles almost on top of the Santa Inez fault, with two tunnels in this reach aggregating about 13,000 feet. At about Mile 525 the line turns through the Santa Inez Range and crosses the Santa Inez main fault zone with a 29,000-foot tunnel located about six miles east of the Bureau of Reclamation's Tecolote Tunnel and three miles west of Santa Barbara's Mission tunnel. From Mile 509 to Mile 535 both cold and hot water may be expected in the fractured and twisted sedimentaries in this area. At Mile 560 a 3½-mile tunnel will penetrate the sedimentaries adjacent to the Ventura oil fields, and finally, just southeast of Ojai, the line traverses "Sulphur Mountain" with a four-mile tunnel in an area in which sulphur, oil, and gas are known to be prevalent. In general it may be said that all the ground to be traversed by the 34 tunnels on this route should be regarded with apprehension and requires thorough geological study, both by surface exploration and extensive diamond drilling, before final locations can be determined.

Design and Estimated Quantities. The state estimate for this route was preliminary and based on layouts on U. S. G. S. quadrangle maps.[1]

The Bechtel estimate for the Wheeler Ridge branch was based on a canal of 2,300 second-feet capacity from Devils Den to Pumping Plant III, however, for the remaining 27 miles an estimated capacity of 600 second-feet was used. Quantities were obtained by prorating previously estimated quantities for this reach.

In reviewing the State's plan, it was assumed that of the six pumping plants, five were designed and estimated to operate on an intermittent basis. Forebays and afterbays were included in the Bechtel estimate for Routes 4 and 5.

Route No. 6—State High Line to Pastoria Creek—Long Tunnel to Castaic Creek Reservoir

General Description. The State also considered an alternate Long Tunnel Route which would terminate at Castaic Creek Reservoir. It is identical to the route subsequently described as Route 7 from the intake to a point near Elizabeth Lake Canyon where it diverts into Castaic Creek Reservoir.

Designs and Estimated Quantities. Comments regarding the main tunnel of the Long Tunnel Line to San Jacinto Portal Route 7 are applicable to this route.

ROUTE NO. 6

COMPARATIVE SUMMARIES OF COST

STATE HIGH LINE TO PASTORIA CREEK—LONG TUNNEL TO CASTAIC RESERVOIR

	State	Bechtel
Oroville Reservoir, Dams and Power Plant, Including Contingencies, Engineering and Administration and Interest During Construction	**$418,661,000**	**$434,384,000**
Feather River Project Acqueduct		
Delta Cross Channel	$8,320,000	$8,960,000
Fish Protective Works	2,400,000	2,400,000
Intake Channel		3,294,000
Pumping Plant No. I	30,223,000	39,373,000
Aqueduct—Intake to San Luis Creek	52,507,000	43,771,000
San Luis Forebay	1,219,000	1,143,000
San Luis Dam and Reservoir	76,130,000	83,831,000
Pumping Plant No. II-A	30,486,000	34,824,000
Pumping Plant No. II-B	24,742,000	31,558,000
Aqueduct—San Luis Creek to Wheeler Ridge	106,681,000	97,290,000
Pumping Plant No. III	12,412,000	15,724,000
Pumping Plant No. IV	13,530,000	21,022,000
Pumping Plant No. V	31,626,000	46,494,000
Pumping Plant No. VI	14,550,000	32,858,000
Buena Vista Forebay	1,452,000	2,724,000
Aqueduct—Wheeler Ridge to Pastoria Creek	10,720,000	9,721,000
Aqueduct—Pastoria Creek to Castaic Creek Reservoir	248,929,000	257,591,000
Castaic Creek Reservoir	12,171,000	15,594,000
Aqueduct—Alameda-Santa Clara-San Benito Branch	28,141,000	28,255,000
Relift Pumping Plant—Alameda-Santa Clara-San Benito Branch	3,122,000	3,936,000
Airpoint Dam and Reservoir	6,835,000	6,504,000
Evergreen Dam and Reservoir	5,492,000	5,584,000
District Offices, Communication Systems, Service Roads, etc.		948,000
Subtotal	$721,688,000	$793,399,000
Contingencies	105,366,000	127,595,000
Engineering and Administration	72,169,000	67,403,000
Interest During Construction	63,957,000	72,644,000
Subtotal Feather River Project Aqueduct	$963,180,000	$1,061,041,000
Total cost	$1,381,841,000	$1,495,425,000

[1] *"Program for Financing and Constructing the Feather River Project,"* State of California, Department of Public Works, Division of Water Resources, February, 1955, p. 11.

Route No. 7—State High Line to Pastoria Creek—Long Tunnel Line to San Jacinto Tunnel Portal

General Description. This route is identical to the basic High Line from the Delta through Pumping Plant No. V at Pastoria Creek with a modified route planned beyond that point. The following discussion therefore applies only to the section beyond Pastoria Creek.

The State's cost estimate for the Long Tunnel Line southward from Pastoria Creek was based upon layouts developed on U. S. Geological Survey quadrangles.[1]

Under this alternate, Pumping Plant VI located at Pastoria Creek would lift water 370 feet into the Long Tunnel Line at elevation 1870. From this point to the San Jacinto Tunnel Portal, the route includes approximately 85 miles of tunnel.

The longest and most critical tunnel from a construction standpoint is through the Tehachapi Mountain between Pastoria Creek and Elizabeth Lake Canyon. This 20-foot diameter tunnel is approximately 26.7 miles long and passes through four major fault zones identified as the Garlock, San Andreas, Liebre and Clearwater faults.

Progress to be anticipated in driving and lining this tunnel is largely dependent on the number and location of the shafts from which the tunnel is to be driven. The State's plan proposes three shafts and two portals which would provide eight working headings. By variations of the assumed locations of the three shafts and the assumed characteristics of ground between the shafts, the time requirements for tunnel construction will differ by as much as four and one-half years. It was therefore believed desirable to establish the most feasible number and location of the shafts for estimating purposes.

Bechtel prepared a new layout of shafts, added one shaft, and realigned the tunnel at the fault zones, so as to reduce the length of tunnel through those fault zones. As a result the time schedule for construction of the tunnel was materially improved and the more difficult portions of the tunnel through major fault zones were more nearly isolated so that they could each be given special attention and treatment. Moreover, if there should be seismic damage, the probable damaged areas would be closer to access points, thus substantially reducing the time for repairs. Bechtel's estimate of costs, after credit was taken for these modifications, reflected final costs that were only approximately 3½ percent higher than state estimates.

Design and Estimated Quantities. The State's cost estimate for the Long Tunnel is based on 20 feet diameter throughout. Bechtel's cost estimate for this tunnel, so dimensioned, is $257,591,000. If no water is delivered to Antelope Valley, and the capacity is reduced from 2,500 to 1,700 cfs., a reduction of approximately $50,000,000 in the cost of the Long Tunnel from Pastoria Creek to Castaic Creek Reservoir is probable.

[1] *"Program for Financing and Constructing the Feather River Project,"* State of California, Department of Public Works, Division of Water Resources, February, 1955, p. 12.

ROUTE NO. 7

COMPARATIVE SUMMARIES OF COST

STATE HIGH LINE TO PASTORIA CREEK—LONG TUNNEL TO SAN JACINTO

	State	Bechtel
Oroville Reservoir, Dams and Power Plant, Including Contingencies, Engineering and Administration and Interest During Construction	**$418,661,000**	**$434,384,000**
Feather River Project Aqueduct		
Delta Cross Channel	$8,320,000	$8,960,000
Fish Protective Works	2,400,000	2,400,000
Intake Channel		3,294,000
Pumping Plant No. I	30,223,000	39,373,000
Aqueduct—Intake to San Luis Creek	52,507,000	43,771,000
San Luis Forebay	1,219,000	1,143,000
San Luis Dam and Reservoir	76,130,000	83,831,000
Pumping Plant No. II-A	30,486,000	34,824,000
Pumping Plant No. II-B	24,742,000	31,558,000
Aqueduct—San Luis Creek to Wheeler Ridge	106,681,000	97,290,000
Pumping Plant No. III	12,412,000	15,724,000
Pumping Plant No. IV	13,530,000	21,022,000
Pumping Plant No. V	31,626,000	46,494,000
Pumping Plant No. VI	14,550,000	32,858,000
Buena Vista Forebay	1,452,000	2,724,000
Aqueduct—Wheeler Ridge to Pastoria Creek	10,720,000	9,721,000
Aqueduct—Pastoria Creek to Elizabeth Lake Canyon	248,929,000	
Aqueduct—Elizabeth Lake Canyon to San Jacinto Tunnel Portal	250,783,000	501,817,000
Aqueduct—Alameda Branch		28,255,000
Relift Pumping Plant-Alameda Branch		3,936,000
Airpoint Dam and Reservoir		6,504,000
Evergreen Dam and Reservoir		5,584,000
District Offices, Communication Systems, Service Roads, etc.		948,000
Subtotal	$916,710,000	$1,022,031,000
Contingencies	148,415,000	171,891,000
Engineering and Administration	91,671,000	80,266,000
Interest During Construction	62,795,000	102,223,000
Subtotal Feather River Project Aqueduct	$1,219,591,000	$1,376,411,000
Total cost	$1,638,252,000	$1,810,795,000

The Long Tunnel would present construction difficulties and would be subject to seismic movement in or near the four major fault areas to be traversed; however, it can be successfully constructed and operated. It must be remembered that seismic movements are inherent, to a greater or lesser degree, in the tunnel portions of all of the routes traversing not only the Tehachapis, but also the Temblor, San Rafael, Santa Lucia and Santa Inez Ranges.

The Long Tunnel passes through the main range of the Tehachapis with a maximum cover of about 3,900 feet. Its construction can be carried out through two portals and four shafts 1,500 to 1,800 feet deep. The shafts should be so located as to be immediately adjacent to major fault zones so that in case of seismic

damage, repairs could be more easily made. A shaft should be located on each side of the San Andreas fault.

The first four miles of the Long Tunnel is in gneiss, rather badly fractured. It then passes into quartz monzonite, a granitic rock lacking in hornblends and heavy with feldspar which breaks down on exposure to air and in presence of water. The Garlock faults (north and south) are passed at Mile 4.6 and while these are rather narrow, they must be given special design consideration.

From Mile 4.8 to Mile 8.9 the rock is sound or moderately weathered Tejon Lookout Granite, which should be fair to good tunnel ground. The route from Mile 8.9 to Mile 14.3 consists of a limited amount of Pliocene lake deposits, but principally of moderately cemented sandstones, shales and conglomerates of the Santa Margarita formation. There may be some gas and oil in this formation. The San Andreas fault zone is between this formation and the granite of Liebre Mountain, and where crossed by the State's route it would be about 3,000 feet in width. By realigning the tunnel this zone could be reduced to approximately 2,100 feet in width. This is the most difficult portion of the tunnel, but similar conditions will undoubtedly be encountered by any tunnel or tunnels designed to carry water from the San Joaquin Valley to Southern California.

From Mile 14.9 to Mile 20.7, the tunnel will probably be in Liebre quartz monzonite, a granitic type rock which is cut by several minor faults. This section has the heaviest cover of the entire tunnel. At Mile 20.7 the tunnel passes into a gneiss formation in which the Clearwater and possibly two other faults are located. Cover is gradually decreasing and water flow will probably be less but may be hot. The outlet portal is at Elizabeth Lake Canyon at Mile 26.7. This Long Tunnel Line is under deep cover in a known faulted area. It will require the best and most extensive underground exploration possible, with the expectation that results may show necessity for important alignment changes.

If a decision is made to construct this Long Tunnel Line, further study is needed regarding feasible tunnel routes in this area. For example, the State made a geological study of a tunnel from the Wheeler Ridge area to daylight in the east part of Santa Clara Valley with inlet at elevation 1500. This route was west of the 1870 tunnel line and traversed the Santa Margarita formation in which oil, gas, hot water and water with some acids could be expected. If this line were moved eastward, it would probably encounter the Mint Canyon formation instead of the Santa Margarita at its south end, and tunnel construction would probably be less difficult. Its length would be about 34 miles from Pastoria Creek to San Francisquito Canyon at about elevation 1380, and 38 miles to Bouquet Canyon, at which point it could deliver into a reservoir of about 40,000 to 50,000 acre-feet. From Bouquet Canyon it could then be carried to a terminal reservoir near Granada Hills in western San Fernando Valley. It would save some 350 feet in pump lift and might be no more hazardous than the 1870 tunnel.

ALTERNATIVES AND MODIFIED PLANS CONSIDERED AND INVESTIGATED BY BECHTEL

Several of the routes proposed and discussed in the State's report as modifications to the High Line Route are not comparable since they do not provide service to the same areas.

It was apparent that certain of the State's modified routes warranted further development and consideration, and that they could be compared on a cost basis if modified and extended to furnish comparable service. To this end Bechtel made quantity and cost estimates on four alternate routes. Each of these routes stems from the State's basic High Line Route, three being modifications and extensions of the State's proposed routes and the fourth being a new and entirely different modification.

Terminal storage is provided for each of these four modified routes at Granada Hills Reservoir, which is a combination of three reservoirs, one each in Bull, Shoshone, and Aliso Canyons, located about two miles north of the town of Granada Hills. These three proposed reservoirs would be interconnected by channels, and would provide a combined storage of 26,500 acre-feet. At maximum water surface elevation of 1,300 feet this storage would supply approximately one week's south coastal water demand.

Route No. 8—Bechtel Alternate—High Line to Devils Den—Extension to Wheeler Ridge—Coastal Route to Castaic Reservoir—Extension to Granada Hills Reservoir

This Bechtel alternate departs from the State's proposed Coastal Line Route 4 slightly upstream from Pumping Plant No. 5.

Under this plan, Pumping Plant No. 5 would be located north of the Southern Pacific Railroad near Del Valle and would consist of 10 operating units and one standby unit. Each pumping unit would have a capacity of 300 second-feet and would lift the water to elevation 1210.

From Pumping Plant 5, the aqueduct continues northeast to Pumping Plant 6. Pumping Plant 6 would be located at the toe of the proposed Castaic Creek Dam and would consist of 10 operating units and one standby unit. Each unit would have the capacity of 300 second-feet and would lift water to elevation 1405, the maximum water surface at Castaic Creek Reservoir. The pumps would be designed to

Scale 1:250,000

5 0 5 Miles

PLATE III-A. ROUTE No. B—BECHTEL ALTERNATE—HIGH LINE TO DEVILS DEN—COASTAL LINE TO CASTAIC RESERVOIR—EXTENSION TO GRANADA HILLS RESERVOIR

ROUTE NO. 8

SUMMARY OF COST

BECHTEL ALTERNATE—HIGH LINE TO DEVILS DEN—COASTAL LINE TO CASTAIC RESERVOIR—EXTENSION TO GRANADA HILLS RESERVOIR

	Bechtel
Oroville Reservoir, Dams and Power Plant, Including Contingencies, Engineering and Administration and Interest During Construction	**$434,384,000**
Feather River Project Aqueduct	
Delta Cross Channel	$8,960,000
Intake Channel and Fish Protective Works	5,694,000
Pumping Plants No. I, II-A, and II-B	105,755,000
Aqueduct—Pumping Plant No. I to San Luis Creek	43,771,000
San Luis Dam and Reservoir-Including Forebay	84,974,000
Aqueduct—San Luis Creek to Wheeler Ridge	86,177,000
Pumping Plant No. III	3,931,000
Coastal Aqueduct—Devils Den to Castaic Creek	409,300,000
Coastal Line Pumping Plants	56,963,000
Castaic Creek Dam and Reservoir	15,594,000
Castaic Reservoir to Granada Hills Reservoir	36,753,000
Granada Hills Reservoir	12,763,000
Aqueduct—Alameda Branch	28,255,000
Relift Pumping Plant—Alameda Branch	3,936,000
Airpoint Dam and Reservoir	6,504,000
Evergreen Dam and Reservoir	5,584,000
District Offices, Communication Systems, Service Roads, etc.	948,000
Forebays and Afterbays for Coastal Pumping Plants	24,000,000
Subtotal	$939,862,000
Contingencies	154,712,000
Engineering and Administration	78,544,000
Interest During Construction	65,343,000
Subtotal Feather River Project Aqueduct	$1,238,461,000
Total cost	$1,672,845,000

ROUTE NO. 9

SUMMARY OF COST

BECHTEL ALTERNATE—HIGH LINE TO PASTORIA CREEK—LONG TUNNEL TO ELIZABETH LAKE POWER DROP AND CASTAIC RESERVOIR—EXTENSION TO GRANADA HILLS RESERVOIR

	Bechtel
Oroville Reservoir, Dams and Power Plant, Including Contingencies, Engineering and Administration and Interest During Construction	**$434,384,000**
Feather River Project Aqueduct	
Delta Cross Channel	$8,960,000
Intake Channel and Fish Protective Works	5,694,000
Pumping Plants No. I, II-A, and II-B	105,755,000
Aqueduct—Pumping Plant No. I to San Luis Creek	43,771,000
San Luis Dam and Reservoir—Including Forebay	84,974,000
Aqueduct—San Luis Creek to Wheeler Ridge	97,290,000
Pumping Plants No. II, IV, and V	83,240,000
Pumping Plant No. VI	32,858,000
Buena Vista Forebay	2,724,000
Aqueduct—Wheeler Ridge to Castaic Creek Reservoir	267,312,000
Elizabeth Lake Canyon Power Plant	3,763,000
Castaic Creek Reservoir	15,594,000
Castaic Reservoir to Granada Hills Reservoir	36,753,000
Granada Hills Reservoir	12,763,000
Alameda Branch—Aqueduct	28,255,000
Alameda Branch—Dams and Reservoirs	12,088,000
Alameda Branch—Relift Pump Plant	3,936,000
District Offices, Communication Systems, Service Roads, etc.	948,000
Subtotal	$846,678,000
Contingencies	136,802,000
Engineering and Administration	71,516,000
Interest During Construction	79,131,000
Subtotal Feather River Project Aqueduct	$1,134,127,000
Total cost	$1,568,511,000

operate against a variable head. At times this plant would also pump directly into the canal leading to Granada Hills Reservoir. All pumps in Plants 5 and 6 would be designed for off-peak pumping.

The estimated construction costs for this Bechtel route modification are shown in the table above.

Route No. 9—Bechtel Alternate—High Line to Pastoria Creek—Long Tunnel to Elizabeth Lake Power Drop and Castaic Creek Reservoir—Extension to Granada Hills Reservoir

General Description. The State proposal to divert water from the Long Tunnel to Castaic Creek Reservoir [1] terminated without development of power or completing delivery of water to Southern California water distribution agencies.

Under this suggested Bechtel alternate the route departs from the State's proposed Long Tunnel Route (Route 6) at station 1300 thence is routed by tunnel to the headwaters of Castaic Creek Reservoir at Elizabeth Lake Canyon. At this terminus, one of two schemes may be adopted: a tunnel portal outlet may be provided to discharge by gravity flow down Elizabeth Lake Canyon to Castaic Creek Reservoir, or a power drop may be constructed with a powerhouse located at Castaic Creek Reservoir. From this reservoir the water would be conveyed by aqueduct to the terminal storage reservoir at Granada Hills as shown on the accompanying map. The power plant would be located at the head of the Elizabeth Lake Canyon area of the Castaic Creek Reservoir.

Design and Quantity Estimates. Of these two schemes, use of a power drop is most advantageous. Total capacity of the power plant would be 39,200 kw. with a net head of 320 feet. Under continuous operation this plant would produce a total of 342,000,000 kwh. annually. The study was based on an assumed continuous flow of 1,700 second-feet in the aqueduct and 78,000 acre-feet of storage in Castaic Creek Reservoir.

Maximum and minimum water surface in the reservoir would be 1,405 and 1,335 respectively. Castaic Creek Reservoir is only about 20 miles by aqueduct to the northwestern part of the San Fernando Valley near Granada Hills, and the only probable construction hazard en route would be the Newhall Gap Tunnel, about seven miles long through sedimentary rocks but with reasonable cover. Cost of this maximum development is roughly estimated at $50,000,000 exclusive of engineering, administration and contingencies.

[1] *Program for Financing and Constructing the Feather River Project,* State of California, Department of Public Works, Division of Water Resources, February, 1955, p. 12.

Scale 1:250,000

5 0 5 Miles

PLATE III-B. ROUTE No. 9—BECHTEL ALTERNATE—HIGH LINE TO PASTORIA CREEK—LONG TUNNEL TO ELIZABETH LAKE POWER DROP AND CASTAIC RESERVOIR—EXTENSION TO GRANADA HILLS RESERVOIR

PLATE III-C. ROUTE No. 10—BECHTEL ALTERNATE—HIGH LINE TO QUAIL LAKE AND CASTAIC POWER DROP—EXTENSION TO GRANADA HILLS RESERVOIR

Power revenues would reduce the cost of water delivered to Southern California. The table on page 62 shows the estimated construction cost of Route No. 9.

Route No. 10—Bechtel Alternate—High Line to Quail Lake and Castaic Power Drop—Extension Granada Hills Reservoir

This alternate route is an extension of the State's Castaic Power Development Plan (Route 3). The extension begins at Castaic Creek Reservoir and terminates at Granada Hills Reservoir as shown on Plate III-C. Features of this route are identieal to those previously described for the Bechtel Routes 8 and 9. Bechtel's eost estimate is shown on Tabulation III-K.

ROUTE NO. 10

SUMMARY OF COST

BECHTEL ALTERNATE—HIGH LINE TO QUAIL LAKE AND CASTAIC POWER DROP—EXTENSION TO GRANADA HILLS RESERVOIR

	Bechtel
Oroville Reservoir, Dams and Power Plant, Including Contingencies, Engineering and Administration and Interest During Construction	**$434,384,000**
Feather River Project Aqueduct	
Delta Cross Channel	$8,960,000
Intake Channel and Fish Protective Works	5,694,000
Pumping Plants No. I, II-A, and II-B	105,755,000
Aqueduct—Pumping Plant No. I to San Luis Creek	43,771,000
San Luis Dam and Reservoir—Including Forebay	84,974,000
Aqueduct—San Luis Creek to Wheeler Ridge	97,290,000
Pumping Plants No. III, IV and V	83,240,000
Pumping Plant No. VI	96,806,000
Buena Vista Forebay	2,724,000
Aqueduct—Wheeler Ridge to Quail Lake	78,762,000
Quail Lake Forebay	8,882,000
Aqueduct—Quail Lake to Ridge Basin	47,837,000
Ridge Basin Power Plant	27,166,000
Ridge Basin Afterbay	2,465,000
Aqueduct—Ridge Basin to Castaic Creek	28,378,000
Castaic Power Plant	40,581,000
Castaic Creek Dam and Reservoir	14,934,000
Castaic Reservoir to Granada Reservoir	36,753,000
Granada Reservoir	12,763,000
Alameda Branch—Aqueduct	28,255,000
Alameda Branch—Dams and Reservoirs	12,088,000
Alameda Branch—Relift Pump Plant	3,936,000
District Offices, Communication Systems, Service Roads, etc.	948,000
Subtotal	$872,962,000
Contingencies	138,099,000
Engineering and Administration	80,240,000
Interest During Construction	54,612,000
Subtotal Feather River Project Aqueduct	$1,145,913,000
Total cost	$1,580,297,000

Route No. 11—Bechtel Alternate—High Line to Mile 500—Cherry, Bouquet and Haskell Power Drops to Granada Hills Reservoir

General Description and Design. This alternate leaves the basic High Line Route at about mile 500 to the San Fernando Valley, terminating at the Granada Hills Reservoir as shown on Plate III-D. Firm

ROUTE NO. 11

SUMMARY OF COST

BECHTEL ALTERNATE—HIGH LINE TO MILE 500—CHERRY, BOUQUET AND HASKELL POWER DROPS TO GRANADA HILLS RESERVOIR

	Bechtel
Oroville Reservoir, Dams and Power Plant, Including Contingencies, Engineering and Administration and Interest During Construction	**$434,384,000**
Feather River Project Aqueduct	
Delta Cross Channel	$8,960,000
Intake Channel and Fish Protective Works	5,694,000
Pumping Plants No. I, II-A, and II-B	105,755,000
Aqueduct—Pumping Plant No. I to San Luis Creek	43,771,000
San Luis Dam and Reservoir—Including Forebay	84,974,000
Aqueduct—San Luis Creek to Wheeler Ridge	97,290,000
Pumping Plants No. III, IV, and V	83,240,000
Pumping Plant No. VI	96,806,000
Buena Vista Forebay	2,724,000
Aqueduct—Wheeler Ridge to Elizabeth Lake Reservoir	110,110,000
Elizabeth Lake Dam, Reservoir, and Spillway	3,265,000
Elizabeth Lake to Power Drop I	22,127,000
Power Drop I—Including Penstocks	41,905,000
Cherry Canyon Dam and Reservoir	851,000
Cherry Reservoir to Drop II	27,136,000
Power Drop II—Including Penstocks	25,856,000
Bouquet Canyon—Reservoir, Dam, and Spillway	3,479,000
Bouquet Canyon Reservoir to Drop III	14,380,000
Power Drop III	12,697,000
Haskell Canyon Reservoir, Dam, and Spillway	2,384,000
Haskell Canyon Reservoir to Granada Reservoir	48,450,000
Granada Hills Reservoir	12,763,000
Alameda Branch—Aqueduct	28,255,000
Alameda Branch—Dams and Reservoirs	12,088,000
Alameda Branch—Relift Pump Plants	3,936,000
District Offices, Communication Systems, Service Roads, etc.	948,000
Subtotal	$899,844,000
Contingencies	143,747,000
Engineering and Administration	81,315,000
Interest During Construction	59,409,000
Subtotal Feather River Project Aqueduct	$1,184,315,000
Total cost	$1,618,699,000

flow of 2,000 cfs. was assumed, via a canal, from the High Line Route to a reregulating reservoir utilizing Elizabeth Lake with neeessary regulation for this flow provided by Quail Lake Afterbay. The water would be conveyed from Elizabeth Lake Reservoir through a system of low-pressure tunnels, siphons, penstoeks and afterbays to three peak-load powerhouses loeated in Cherry, Bouquet, and Haskell Canyons. Total dependable generating capacity of the powerhouses would be 566,000 kw. and about 2,210 million kilowatt hours of usable energy could be developed annually.

Quantity estimates are approximate and based on layouts made on U. S. Geological Survey quadrangles at a scale of one inch equals 2,000 and without benefit of investigations at the site. However, it is believed that site conditions would not vary greatly from those assumed and that estimated quantities are representative of conditions that would be encountered during construction.

Elizabeth Lake Reservoir has a live storage capaeity of 10,000 aere-feet which provides regulation between the 2,000-cfs. continuous inflow and the 4,480-

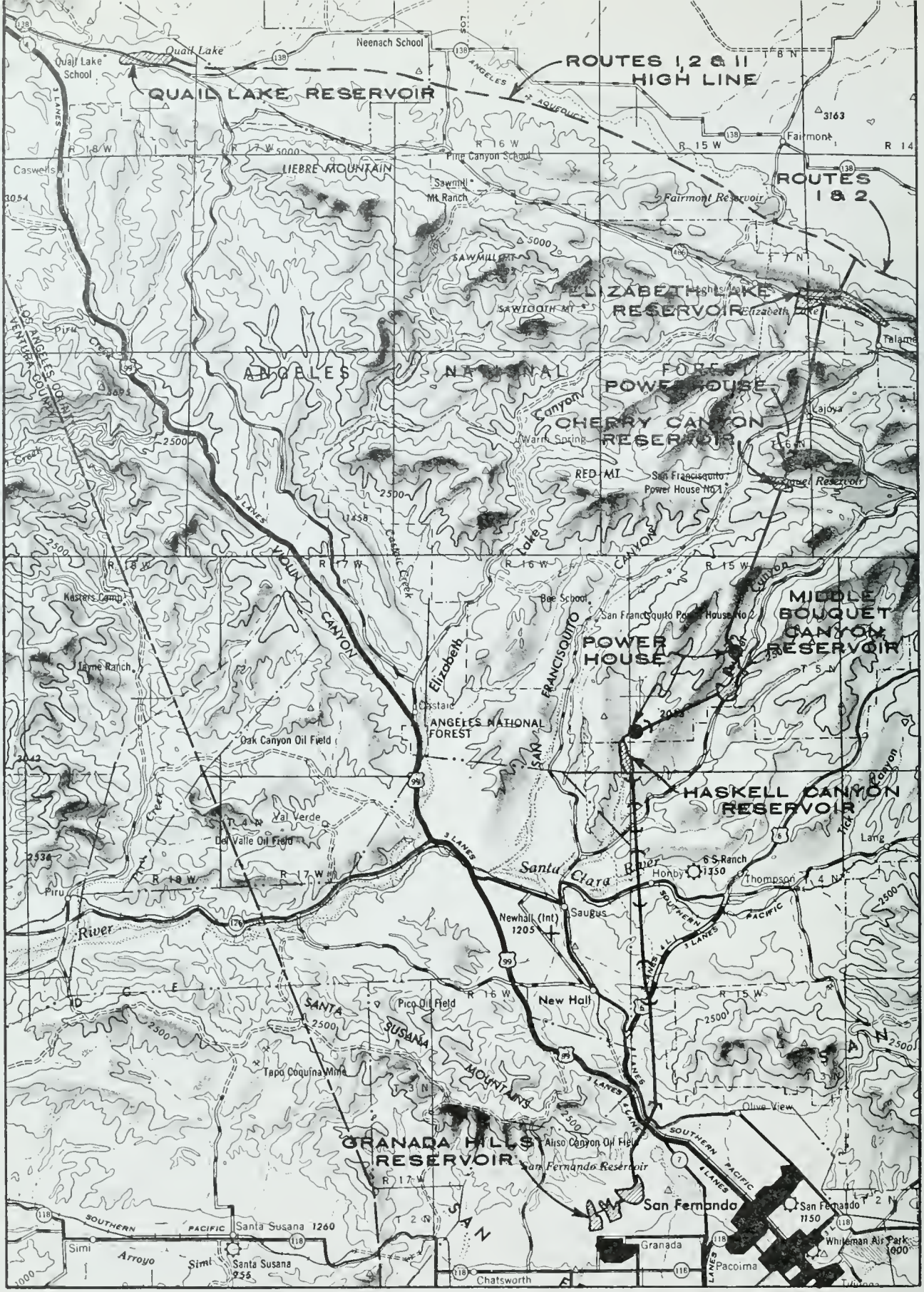


PLATE III D. ROUTE No. 11—BECHTEL ALTERNATE—HIGH LINE TO MILE 500—CHERRY BOUQUET AND HASKELL DROPS TO GRANADA RESERVOIR

cfs. intermittent outflow required for 75 hours per week of power generation during peak load periods. A small amount of live storage is provided in each of the afterbay reservoirs to permit minor variations in the flow through the power conduits. An impervious-core, random-fill type, was assumed for each of the four dams. Hydraulic heights vary from 55 feet to 160 feet. A free overflow spillway, adjacent to each dam, to handle surplus inflows to the reservoirs has been included in the estimates.

Since they are located within an active seismic area, Elizabeth Lake and Cherry Canyon reservoirs do not provide assured protection against interrupted flow which may result from seismic action. Bouquet and Haskell Canyon reservoirs would provide some protection and, in this plan, their capacity is estimated to be approximately 30,000 acre-feet.

About 17.5 miles of low-pressure tunnels, finished to a 22-foot horseshoe, and about 5.8 miles of siphons, either double-barrel 16-foot diameter or single-barrel 22.5-foot diameter, are required for the three power conduits. A conventional gated intake structure is provided at the entrance to each power conduit. The surface penstocks, one for each unit, leading to the powerhouses consist of Tri-ten pipe sections joined by Dresser couplings. Estimates include a butterfly valve near the top of each penstock and a differential surge tank upstream from the wye branch. A bypass system with Tri-ten pipe, control valves and discharge valves, is included in the estimates, to permit maintenance work on the units without affecting flow into the power-drop system.

Pertinent data concerning powerhouses is as follows:

Powerhouse location	*Gross head feet*	*Net head feet*	*Q cfs.*	*Dependable generating capacity No. units*	*kw.*	*Usable energy million kwh./yr.*
Cherry Canyon	915	860	4480	3	288,000	1,125
Bouquet Canyon	600	555	4480	2	186,000	725
Haskell Canyon	300	275	4480	2	92,000	360

The estimated construction costs for this Bechtel Route modification are shown in Tabulation III-L.

OPERATION AND MAINTENANCE

Replacements

The report of the State Engineer proposes establishing a fund for replacement of items whose estimated life is less than the payout period of the project. No replacement is provided for any item whose estimated life is greater than the payout period of the project. The fund was calculated on a sinking fund basis using interest at 2½ percent. Bechtel concurs in this method.

A comparison of a replaceable item list prepared by Bechtel and the State's detailed cost estimates showed that all major items which could reasonably be considered as replaceable had been included.

The general problem of replacements is contingent upon the degree of maintenance which is present throughout the life of the project, and the quality of materials and workmanship in the original plant. Furthermore, there is a fine line of demarcation between maintenance expense and replacement. This makes it difficult to predict which charges will be allocated to maintenance, and which to replacement. Bechtel has also concluded that the State's allocations for maintenance are fully adequate. It is expected that the original plant will represent the best engineering and construction practices and this will tend to reduce replacement costs.

Therefore, it is concluded that the State's basic assumptions from which replacement costs were computed are sound and that, based on the State's estimate of first cost, the amounts allocated for replacements would be adequate for the purpose for which they are intended. However, due to the increased first cost, as reflected in the Bechtel construction cost estimates, it is recommended that annual replacement costs be increased commensurately as computed by Bechtel.

Operation and Maintenance

The State considered operation and maintenance costs as those costs directly attributable to operation of project features. These costs include salaries, materials and supplies, and motor vehicle and major equipment expense.

Bechtel's detailed analysis and review of personnel requirements indicate that:

The State's proposed "General Expense" organization chart, as well as the allowance made for rent and other miscellaneous expenses, is reasonable.

The State's proposed organization for the Oroville features is reasonable.

Considering the number of units at each of the Feather River pumping plants and the personnel assigned thereto, and comparing the results with the number of personnel at the Tracy Pumping Plant, it is believed that the proposed organization for the Feather River Project Pumping Plants is reasonable, except at Pumping Plants No. 1, II-A, and II-B. Recommended operating personnel at these plants is as follows:

Pumping Plant I—8-1,375 cfs. Units—Continuous Operation, and Santa Clara Diversion Pumping Plant 6-70 cfs. Units—Continuous Operation

	Men per shift		
	Total	*No. I and Santa Clara operating*	*No. I only operating*
Shift supervisors	4	1	1
Operators	8	3	1
Assistant operators	8	2	2
Totals	20	6	4

Pumping Plants No. II-A and II-B—8-1,000 cfs. Units Each: Organization for Continuous Operation

	Total	Men per shift
Associate electrical engineer	1	--
Shift supervisors	4	1
Operators	14	3.5
Assistant operators	14	3.5
Total	33	8

The operating organization proposed by the State appears adequate for operation of Plants No. II-A and II-B on an off-peak basis.

The proposed state organization for canal operation and maintenance is adeqnate.

Bechtel's conclusions with respect to the state allocations for vehicle and major equipment expense and materials and supplies are as follows:

The allocation for the Oroville Dam and Reservoir features appears to be reasonable and adequate.

The allocation for the pumping plants appears to be reasonable and adequate.

The allocation for canals varies from $600 per mile to $679 per mile whereas the Bureau of Reclamation expenses vary from $644 per mile to $870 per mile. This is an expense which may vary widely depending upon local conditions from year to year. Considering the many variables, the state allocation for canals appears adequate for a preliminary estimate.

Total Estimated Operation and Maintenance Costs

An analysis was made of the total estimated costs allocated by the State for general expense and for operation and maintenance.

The Bechtel analysis shows that approximately $3,090,000 shonld be allocated annually for operation and maintenance expense, exclusive of the annual salaries of the additional operating personnel recommended at Pumping Plants No. I and II. It is therefore recommended that the allocation for operation and maintenance annual costs for the High Line location be increased from $2,880,000 to $3,169,000.

Permanent Housing

The State has allocated $428,000 for construction of permanent housing features in the vicinity of Oroville. In addition, an allowance of $121,000 was made for utilities and site work in the vicinity of the dam site. This amount includes permanent roads in the housing area and since details have not been prepared, it is not known what portion of the latter amount is properly chargeable to permanent housing.

In regard to hydroelectric projects in isolated locations, it is common practice among utility companies to provide housing for operations and maintenance personnel. However, this practice is usually limited to locations so isolated that adequate private housing is not available in the area. Since Oroville Dam site is only five miles from the town of Oroville, which has a population of approximately 5,400 persons, the need for state financed permanent housing at the dam site is questioned.

In order to recruit and retain suitable employees for operation and maintenance of the Oroville features, it is necessary, however, that the area provide suitable housing for those employees and their families. If such accommodations are available in the Oroville community at reasonable rates, then the state allocation for permanent housing can be reduced or eliminated altogether.

It is recognized that the availability of adequate permanent housing improves employee morale; however, it is suggested that the requirements for permanent housing be re-examined when the plant construction phase at Oroville is near completion.

The State made no allocation for permanent housing at locations other than at Oroville Dam site and Bechtel's review of pumping plant locations indicates that state-financed housing should be unnecessary in these areas. In all cases the pumping plants appear to be within reasonable commuting distance of established towns.

POSSIBLE MODIFICATIONS AND ALTERNATES

When considering alternate arrangements or modifications of project features, attention must be given to their over-all effect on related components. For example, varying Oroville Reservoir capacity or water releases will change the operation of the power house at Oroville Dam, Pumping Plants No. I, II-A and II-B and San Luis Reservoir. Varying service areas or their schedule of deliveries can change operational requirements of the entire project. The alternate considerations covered in the following discussion are:

Comparative cost of water in the Delta,
Potential postponement of completion date of Oroville Reservoir,
Modification of Oroville Reservoir water releases,
Modification of San Luis Reservoir Afterbay and Pumping Plants No. II-A and II-B,
Value of the surplus capacity of the Delta-Mendota Canal with respect to the Feather River Project,
Comparison of alternate routes to Southern California,
Modification of State's Schedule of water deliveries,
Bechtel operational and route modifications.

Comparative Cost of Water in the Delta

Water availability studies have confirmed that the Delta flow must be supplemented by an additional source of regulated flow to meet ultimate water commitments proposed for the Feather River Project by the State. It is proposed that Oroville Reservoir provide this supplemental supply. Oroville Reservoir assures the project a firm source of supplemental water with seasonal carryover capacity which, when

operated in conjunction with San Luis Reservoir, would meet ultimate project demands through a three- or four-year adverse water cycle. Oroville Reservoir provides a single unit source of supplemental water control and would regulate the flow of the Feather River with minimum spillway discharge. By increasing water availability in the Delta during periods of low flow with supplemental Oroville Reservoir releases, maximum economical use can be made of the capacities of Pumping Plants No. I, II-A and II-B. Oroville Reservoir operation is well suited to the physical requirements of the Feather River Project Aqueduct.

For comparison purposes only, if the Trinity Division were developed on the same basis as the Oroville Project, the average cost of supplemental water in the Delta during a 40-year amortization period for an average water year would be approximately $3.90 per acre-foot. This figure compares with approximately $3.60 per acre-foot from Oroville Reservoir.

Potential Postponement of Completion Date of Oroville Reservoir

Solely on the basis of water availability in the Delta, Bechtel's hydrology studies find that regulated flows from Oroville would not be required before annual water deliveries reached approximately 2,900,000 acre-feet. Further studies indicated that on-peak power requirements at Pumping Plants No. I, II-A and II-B would increase rapidly after 1971 over the State's estimates if the completion of the construction of Oroville Reservoir was delayed beyond this date when required water deliveries are estimated to be 1,728,000 acre-feet annually. Savings resulting from the reduction of approximately 96,000 kw. on-peak power at Pumping Plant No. I by 1976, or whenever water deliveries reached 2,494,000 acre-feet annually, would amount to $2,736,000 annually, increasing to $5,470,000 when deliveries reached 2,890,000 acre-feet. Completion of the construction of Oroville Reservoir when a 2,494,000 acre-feet project water delivery is required can then be justified on the basis of annual project pumping costs.

Flood control benefits as a matter of public policy rather than economies, the possibility of a more rapid buildup of project water demand than now estimated or licensing procedures of the Federal Power Commission may contribute to the justification of earlier construction of Oroville Dam.

Modifications of Oroville Reservoir Water Releases

Modifying water releases from Oroville Reservoir so that the on-peak power requirements at Pumping Plant No. I can be reduced by 97,200 kw. will offer net annual savings of approximately $2,146,000. To accomplish the annual savings in purchased power costs, the dependable generation at Oroville Power Plant is reduced from 410,000 to 380,000 kw.

As a result of capacity limitations and in order to provide water release flexibility during adverse water years, kw. hr. generation at times would be in excess of that specified as salable on Table 10, Page 17 of the State's 1955 report. Since the project requires considerable purchased power. Oroville secondary power that can be reliably available can be credited to the project, the Pacific Gas and Electric Company's system delivering exchange power to Pumping Plant No. I for an appropriate service charge. Such an arrangement regarding the State's surplus power was suggested by P. G. & E. letter dated August 17, 1954, which is included in Appendix G of the State's report.

During times when water is plentiful, Oroville can be operated as proposed by the State, the difference between 410,000 and 380,000 kw. becoming nondependable power which would be available 50 percent of the operating years.

Reduction of monthly maximum flows from Pumping Plant No. I to the San Luis Forebay enables Pumping Plants No. II-A and II-B to use off-peak power entirely to maintain the forebay level. However, unless the San Luis Reservoir Afterbay is modified, the on-peak capacity savings at Plant I would be partially canceled in some years by increased on-peak demand at Plant II-A. The necessary modifications required are discussed in the following section.

Modification of San Luis Reservoir Afterbay and Operation of Pumping Plants Nos. II-A and II-B

As previously discussed, when the water level in San Luis Reservoir drops below the afterbay level, power required to pump water from the forebay to the afterbay will be all on-peak at Pumping Plant No. II-A. When the project reaches ultimate development, maximum charges will be incurred if this condition happens during the months of July or August. On-peak demand required for Plant II-A will approach a maximum of 161,000 kw. With Oroville operation modified and taking advantage of the unused portion of the on-peak demand available to Pumping Plant No. I, one or two pumps could be operated on-peak at Pumping Plant No. II-A without increasing demand requirements of the total project. Thus the net increase in on-peak demand as a result of low reservoir levels would range from 115,000 to 138,000 kw. In view of an annual net charge ranging from $3,278,000 to $3,933,000 for this demand, consideration was given to finding an alternate arrangement which would permit economical use of the last 560,000 acre-feet storage in San Luis Reservoir. This storage capacity assumes greater importance when possible seasonal diversities in irrigation supply in excess of these shown by the State are considered. It was therefore concluded that an afterbay with approximately 15,400

acre-feet of live regulated storage is required at the head of the canal south of San Luis since the afterbay proposed by the State serves only as a stilling basin for Pumping Plant No. II-A and San Luis Reservoir discharges to the canal.

Examination of U. S. Geological Survey Quadrangle Maps indicates that the south end of San Luis Reservoir might be modified to enlarge the afterbay storage, at an estimated cost of about $20 million. Four two-speed pumps in Pumping Plant No. II-B would then be relocated in Pumping Plant No. II-A, with discharge penstocks connecting to both the afterbay and the reservoir. Pumping Plants No. II-A and II-B should be consolidated for operating and control purposes. The relative position of the units with respect to the reservoir and afterbay as proposed by the State can be retained. The net savings resulting from the afterbay construction would be approximately $1,473,000 annually and the afterbay enlargement is an operating necessity for on-peak cost reductions at Pumping Plant No. I. The combined annual net savings at Pumping Plants No. I, II-A and II-B would be $3,619,000 after the project reached ultimate development. These savings would equal the increased cost for the enlarged afterbay within about five years and would produce a total net savings of over $134,000,000 throughout the 70-year payout period of the project. The above figures do not include savings which result from reduction of head as more water can be pumped direct from the forebay to the larger afterbay, by-passing the reservoir.

Value of the Surplus Capacity of the Delta-Mendota Canal With Respect to the Feather River Project

There is surplus capacity in the Delta-Mendota Canal during certain months of the year and the Bureau of Reclamation proposes to use this capacity in conjunction with a 1,000,000 acre-feet San Luis Reservoir to supply 1,250,000 acre-feet of water annually to a portion of the San Joaquin Valley. The report of the Regional Director, dated May 6, 1955, stated that the Central Valley Project, San Luis Unit could "be coordinated readily with the Feather River Plan of the State of California, when constructed."

The Feather River Project proposes to supply 3,880,000 acre-feet of water annually. Its proposed service area includes all of the west side of the San Joaquin Valley beyond San Luis Reservoir, plus Southern California. The State's water deliveries would be 2,630,000 acre-feet more than those proposed by the bureau. Since the objectives of the two plans are not comparable, the U. S. B. R. San Luis Unit cannot be considered as a substitute for any portion of the State's Feather River Project without first providing similar total accomplishments. The U. S. B. R. Central Valley Project considers its operation on a unit basis and any new additions to the system are evaluated only after being integrated into the complete system. Comparisons are then based on the resultant operations and total net benefits.

It is accepted that surplus capacity exists in the Delta-Mendota Canal but to use this surplus capacity, the operation of the Delta-Mendota Canal would have to be coupled with San Luis Reservoir. The State recognized that such surplus capacity exists and in early studies used it, supplemented by a new 7000 cfs. canal from the Delta to provide its San Luis requirements. In their final studies, however, the State substituted an 11,000 cfs. canal for the above combination. The San Luis Reservoir as proposed by the State would provide an ultimate storage capacity of approximately 2,100,000 acre-feet of water to meet ultimate project requirements. The Bureau of Reclamation proposes to build a 1,000,000 acre-feet reservoir with provision for raising at a later date.

Bechtel finds that there is no present assurance that the surplus capacity of the Delta-Mendota Canal can be used for Feather River Project Service where operation of the Delta-Mendota Canal, or any of its capacity, is for purposes separate from the Central Valley Project system.

When determining what the price of water should be from the Delta-Mendota Canal at San Luis Creek, power costs for pumping at Tracy would become a complex factor. Power presently used by the Bureau for the CVP at the Tracy Pumping Plant is charged at 2.5 mills per kw.-hr. Use of the surplus capacity of the Delta-Mendota Canal with power for pumping furnished by CVP would require water releases from CVP storage reservoirs solely for power generation at times when there are surplus water flows in the Delta. No direct CVP irrigation benefits would be realized from such releases. It is, therefore, probable that the price for water delivered by the CVP to the State at San Luis Creek would be determined by appropriate proportioning of the total CVP operating expenses.

Use of surplus capacity in the Delta-Mendota Canal to supplement a 7000 cfs. Feather River Project aqueduct in lieu of providing the 11,000 cfs. aqueduct as proposed by the State, would result in a material increase in the Feather River Project on-peak power requirements. Bechtel studies indicate that the resultant increase in total operational costs would reach a magnitude during the amortization period that would more than equal initial economic advantages of using the existing Delta-Mendota Canal.

For example, assuming amortization of construction bonds in 70 years, it is indicated that the maximum price which the State could afford to pay the CVP for water from the Delta-Mendota Canal at San Luis Creek would range between $3.50 per acre-foot in 1961, decreasing to zero by 1979. The U.S.B.R. San Luis Report specifies $3.50 an acre-foot for Class 1

water supply for the San Joaquin Valley and Delta areas presently served by existing facilities.

Comparison of Alternate Routes to Southern California

The State's report asserts that assumed allocations of project water to various service areas have been made for purpose of ascertaining physical and engineering feasibility of the system and that as such, these allocations are not to be considered as a recommendation for project water distribution. It is further stated in the state report that the several suggested routes are not alternatives as they would not furnish service comparable to that obtainable from the basic route which is referred to as the "High Line Route."

The total water deliveries as proposed by the State are 3,880,000 acre-feet in all of the various alternates considered. The distribution of this quantity of water among the various service areas and the selection of route affects the aquednct and pumping plant sizes and the costs related thereto. The rate of buildup of water demands in the service areas will determine the water charges required to provide the necessary funds to amortize and operate the project. These water charges will in turn influence the rate of buildup. As a starting point, by assuming specific water delivery buildup rates for the areas to be served by the project, an empirical basis is available for determining the cost of water to the respective service areas. These costs must then be compared with the ability of the water users to pay the required charges before the economic feasibility of any alternate can be compared. A practical approach to the problems as to which areas should be served by the Feather River Project, to what extent, and by what routes is to determine by summary comparison which of the alternate routes will deliver water to the service areas at the most economical levels for the respective water allocations proposed by the State. Such comparisons will enable a few plans to be isolated for more detailed study. These plans can then be modified so that the rate of development of water deliveries will be consistent with the ability of the users to pay for the water as well as with their estimated requirements.

Bechtel made a comparison of the delivered cost of water per acre-foot for the State's seven alternate plans plus four modifications considered by Bechtel. All of the plans are fully described in the aqueduct section of this report. The results are summarized on the following tabulation.

The costs of water shown in the tabulation are for comparison purposes only.

The "proportionate use" method was used by both the State in their preliminary work and by Bechtel in this review. Water costs determined on this basis assume that the service area will be charged on the basis of its proportionate use of the facilities. When the water demand in areas served by the upstream facilities reaches its maximum allocation prior to full development of the downstream facilities, a heavier amortization charge is born by the upstream customers. The upstream facilities would not be amortized proportionately by all areas using these facilities. The upstream customer would, however, derive some benefit from lower construction costs per unit of aqueduct capacity as a result of the enlarged facilities. Such problems are beyond the scope of this report, and any attempt to solve them at this time would involve such detail as to make it impossible to compare the many alternate routes within the time allotted.

The average cost of water at each service area was computed by first obtaining the cumulative costs credited to that service area and dividing this total by the cumulative water deliveries passing through the reach in question throughout the 71-year operating period shown in the State's financial analysis. This incremen-

SUMMARY COMPARISON OF THE DELIVERED COST OF WATER

Route No.	Description	Cost of water in dollars per acre-foot			
		Fresno, Kings, N. Kern Counties	S. Kern County	Alameda, Santa Clara, San Benito Counties	Southern California
1	State High Line to Barrett Reservoir	$9.08	$10.74	$15.68	$41.61
2	State High Line to San Bernardino and Devil Canyon Power Drop	9.08	10.74	15.68	32.90
3	State High Line to Quail Lake and Castaic Power Drop	9.08	10.74	15.68	28.69
4	State High Line to Devils Den—Coastal Line to Castaic Creek	9.03	12.41	15.68	36.99
5	State High Line to Devils Den—Coastal Line to San Jacinto	9.03	12.41	15.68	47.49
6	State High Line to Pastoria Creek—Long Tunnel to Castaic Creek Reservoir	9.08	10.74	15.68	34.21
7	State High Line to Pastoria Creek—Long Tunnel to San Jacinto	9.08	10.74	15.68	43.66
8	Bechtel Alternate—High Line to Devils Den—Coastal Line to Castaic Reservoir—Extension to Granada Hills Reservoir	9.03	12.41	15.68	38.49
9	Bechtel Alternate—High Line to Pastoria Creek—Long Tunnel to Elizabeth Lake Power Drop and Castaic Reservoir—Extension to Granada Hills Reservoir	9.08	10.74	15.68	34.96
10	Bechtel Alternate—High Line to Quail Lake and Castaic Power Drop—Extension to Granada Hills Reservoir	9.08	10.74	15.68	29.92
11	Bechtel Alternate—High Line to Mile 500—Cherry, Bouquet and Haskell Power Drops to Granada Hills Reservoir	9.08	10.74	15.68	30.58

NOTE: In calculating water costs per acre-foot for Routes 4, 5 and 8 (Coastal Lines) it was assumed that the 576,000 acre-feet of water allocated to Antelope Valley under the High Line Route would be reallocated to Fresno, Kings and Northern Kern Counties.

tal unit cost thus obtained for each service area was then added to the unit's incremental cost for water from the intake at the Delta to the reach in question. For example, the unit cost for water delivered to Southern California by the High Line Route would be the sum of the incremental unit costs at Pumping Plant No. I, Fresno-Kings and Northern Kern County, Southern Kern County and the increment from Pumping Plant No. IV to Barrett Reservoir. This procedure ignores interest payments on General Fund contributions. The comparisons relate to alternate methods of delivering water to Southern California. Since all plans are predicated on similar rates of buildup of water deliveries to Southern California (Antelope Valley excepted) the expenses related to constructing these facilities will parallel each other. Neglecting interest repayment on General Fund contributions will tend to minimize the effect that cost differentials among the alternate plans would have on required costs of water for each plan to make the projects self-liquidating. Therefore, in the above comparisons the relative high-low difference in the costs for water for Southern California would be greater if the projects were put on a self-liquidating basis. Calculations of present worth of General Fund contributions and of revenues in excess of annual expenses are not necessary for the comparison.

Bechtel cost estimates were used. Interest during construction was calculated at 2.5 percent. Debt service included 2.5 percent bonds amortized over a straight 40-year period. Bechtel costs for operation, maintenance and replacement, as well as for general expenses, were used and correspond closely to state values. The cost of pumping was based on an average year computed for each service area on the basis of rates quoted by the P. G. & E. The power costs used approximate the State's estimates for Pumping Plants I, II-A and II-B. In the comparisons used by Bechtel in this review, power revenues south of the Tehachapi Mountains were credited entirely to Southern California, as the power drops available are a direct result of the high lifts specifically required for delivery to Southern California and assist in the repayment of facilities for their sole use; otherwise, there would be no equitable basis for comparing the alternate routes.

Routes No. 1 through 7 on the above table are as reported upon by the State. The "High Line" plans provide for a more complete delivery of 1,800,000 acre-feet of water to the Southern California areas than do the Long Tunnel and coastal plans. The State's report financial analyses are based on indicated charges for water per acre-foot and do not necessarily reflect the "proportionate use" cost of water. The water charges selected produce varying balances in general fund contributions vs. revenues in excess of annual expenses. The present worth balance of these two components also varies for the alternate plans so that no two plans can be compared on an equal basis. No basis has been provided by the State Report for evaluating the relative cost of serving the several areas in Southern California.

The water costs shown on the preceding tables for Routes No. 1 through 7 could not be expected to agree with the State's financial tables, and are reduced to a common base for comparison purposes only. Route No. 2 has been extended to Lake Mathews and Morris Reservoir by Bechtel. State cost estimates for Route No. 7 did not include the cost of the Alameda-Santa Clara-San Benito Branch, and this was added by Bechtel.

During the course of the Bechtel studies, delivery of water to the Granada Hills Reservoir, through the Castaic Power Development, appeared to have advantages both with respect to total annual costs and a basis for making forecasts of water requirements. This is shown as Route No. 10 on the table. The other Bechtel Routes No. 8, 9 and 11 are also terminated at Granada Hills Reservoir. Routes No. 8 through 11 then offer an equivalent basis for comparisou.

The following conclusions were derived from the above summary comparison of Routes No. 1 through 11.

Routes No. 3, 10 and 11 demonstrate sufficient comparative cost advantages to warrant adoption of one if the cost of water is the deciding factor.

The Devil Canyon Power Development, Route No. 2, is the next most attractive route on the same basis.

Route I, the High Line, and Routes No. 6, 7 and 9, involving the "Long Tunnel," result in appreciably higher acre-foot costs of water than other plans through the Tehachapis.

Routes No. 4, 5 and 8, involving the Coastal Route, are also among those resulting in higher cost to Southern California.

"Power drops" in Southern California have the effect of materially reducing costs of delivered water, when they are an essential feature of any plan and are operated to produce the amount of on-peak power intended.

Modification of State's Schedule of Water Deliveries

As a basis for making a more detailed analysis of specific plans developed above, the results of the economic studies discussed in subsequent sections of this text were incorporated in the Bechtel operational and route modifications for financial analysis. The schedule of water deliveries, based upon Bechtel water demand studies expressed in 1,000 acre-feet, is shown by the tabulation on the following page.

Operational and Route Modifications

Routes No. 8 and 10 were selected for further detailed comparison purposes. Route No. 10, which incorporates the High Line to Quail Lake, the Castaic

Power Development and aqueduct extension to Granada Hills, supplies water to the San Fernando Valley area of Southern California at the lowest unit cost.

Route No. 8 is in the high range with respect to the cost of water to the same point in Southern California, but offers a comparison between two plans furnishing equivalent services. Such a comparison will substantiate the results of the analysis previously discussed and will indicate, to a greater degree of accuracy, the range of differences in water costs to Southern California for the alternate plans. In the following paragraphs Routes No. 8 and 10 will be referred to as Routes No. 8A and 10A. The latter include the following additional modifications:

On the basis of Bechtel's studies of water availability in the Delta and pumping plant power studies, the construction of Oroville Reservoir in the financial studies was delayed so that its operation would begin in the year 1976.

WATER DEMAND

(1,000 Acre-feet)

Year	Fresno Kings and N. Kern Co.	S. Kern Co.	Alameda, S. C. and S. B. Co.	Southern California	Total
1959	405	--	--	--	405
60	539	--	--	--	539
61	674	--	--	--	674
62	808	--	--	--	808
63	943	53	--	--	996
64	1,042	63	50	--	1,155
1965	1,141	73	58	--	1,272
66	1,240	83	66	--	1,389
67	1,339	93	74	--	1,506
68	1,438	102	82	--	1,622
69	1,495	112	90	--	1,697
1970	1,552	122	100	--	1,774
71	1,609	132	105	--	1,846
72	1,666	142	110	--	1,918
73	1,724	151	115	--	1,990
74	1,772	161	120	--	2,053
1975	1,820	171	125	--	2,116
76	1,868	181	130	200	2,379
77	1,916	191	135	300	2,542
78	1,965	201	140	400	2,706
79	1,985	201	145	500	2,831
1980	2,005	201	150	600	2,956
81	2,026	201	155	680	3,062
82	2,046	201	160	760	3,167
83	2,066	201	165	840	3,272
84	3,087	201	170	920	3,378
1985	2,107	201	175	1,000	3,483
86	2,127	201	180	1,060	3,568
87	2,147	201	185	1,120	3,653
88	2,168	201	190	1,180	3,739
89	2,188	201	195	1,224	3,808
1990	2,208	201	200	1,224	3,833
91	2,215	201	204	1,224	3,844
92	2,215	201	208	1,224	3,848
93	2,215	201	212	1,224	3,852
94	2,215	201	216	1,224	3,856
1995	2,215	201	220	1,224	3,860
96	2,215	201	224	1,224	3,864
97	2,215	201	228	1,224	3,868
98	2,215	201	232	1,224	3,762
99	2,215	201	236	1,224	3,876
2000–2026	2,215	201	240	1,224	3,880

The net power savings at the pumping plants in conjunction with the modified operation of Oroville Reservoir as discussed previously are included. This required the provision of a regulated afterbay of an appropriate size at the discharge of Pumping Plant No. II-A. Operation, maintenance, and replacement costs were adjusted to include modifications at San Luis Reservoir and Pumping Plants Nos. II-A and II-B. Water deliveries shown in the foregoing table were allocated to the service areas. Power generation facilities for the Castaic Power Development were provided based on an assumed ultimate annual water flow of 1,224,000 acre-feet to the Granada Hills terminal. Power revenues were calculated on the basis of rates of $18.60 per kw. year demand and 3.1 mills per kwhr. as quoted by the Southern California Edison Company in their letter dated November 4, 1955, directed to the State Engineer.

Increasing the allocated deliveries to the San Joaquin Valley for Route No. 10-A required enlarging the aqueduct to provide 1,000 cfs. additional capacity from the San Luis Reservoir afterbay discharge to the Buena Vista forebay since greater seasonal variations exist in the Fresno-Kings County Service Area than for the deleted water supply originally scheduled for Antelope Valley. An 8,000 cfs. aqueduct is provided from San Luis Reservoir to the Fresno-Kings County

ROUTE NO. 8A

SUMMARY OF COST

BECHTEL ALTERNATE WITH MODIFICATIONS TO WATER DELIVERY SCHEDULE AND AFTERBAY AT SAN LUIS—HIGH LINE TO DEVILS DEN—COASTAL LINE TO CASTAIC RESERVOIR—EXTENSION TO GRANADA HILLS RESERVOIR

	Bechtel
Oroville Reservoir, Dams and Power Plant, Including Contingencies, Engineering and Administration but without Interest During Construction	**$394,013,000**
Feather River Project Aqueduct	
Delta Cross Channel	$8,960,000
Intake Channel and Fish Protective Works	5,694,000
Pumping Plants No. 1, II-A, and II-B	105,755,000
Aqueduct—Pumping Plant No. I to San Luis Creek	43,771,000
San Luis Dam and Reservoir—Including Forebay	84,974,000
Afterbay Modification at San Luis Dam	
Afterbay	9,956,000
Penstock Modification	5,127,000
Aqueduct—San Luis Creek to Wheeler Ridge	95,793,000
Pumping Plant No. III	5,241,000
Coastal Aqueduct—Devils Den to Castaic Creek	409,300,000
Coastal Line Pumping Plants	56,963,000
Castaic Creek Dam and Reservoir	15,594,000
Castaic Reservoir to Granada Hills Reservoir	36,753,000
Granada Hills Reservoir	12,763,000
Aqueduct—Alameda Branch	28,255,000
Relift Pumping Plant—Alameda Branch	3,936,000
Airpoint Dam and Reservoir	6,504,000
Evergreen Dam and Reservoir	5,584,000
District Offices, Communication Systems, Service Roads, etc.	948,000
Forebays and Afterbays for Coastal Pumping Plants	24,000,000
Subtotal	$965,871,000
Contingencies	159,302,000
Engineering and Administration	81,145,000
Interest During Construction, Oroville Dam and Aqueduct	111,012,000
Total cost	$1,711,343,000

line and a 5,000 cfs. aqueduct from there to the Buena Vista forebay. The capacity of Pumping Plant No. III was reduced to 4,300 cfs. and the capacity of Pumping Plants Nos. IV, V and VI was reduced to 3,400 cfs. as a result of deleting deliveries to Antelope Valley. Amortization and operation, maintenance and repair costs were reduced accordingly. Power costs for Pumping Plants Nos. III, IV, V and VI were calculated on the basis that the plants would operate only during off-peak hours. The Bechtel costs for the aqueduct from Pumping Plant No. III to the Quail Lake afterbay include allowances for providing the necessary forebays and afterbays, or additional canal capacity as a substitute for the same which may be required to adequately regulate the intermittent canal flows as a result of off-peak pumping. During the detailed design stage of the project it may be possible to effect cost reductions on a relative basis for these features. The costs for the Castaic Power Development include margins for extra generating capacity which may be required for diversity in hours of operation.

ROUTE NO. 10A

SUMMARY OF COST

BECHTEL ALTERNATE WITH MODIFICATIONS TO WATER DELIVERY SCHEDULE AND AFTERBAY AT SAN LUIS—HIGH LINE TO QUAIL LAKE AND CASTAIC POWER DROP—EXTENSION TO GRANADA HILLS RESERVOIR

	Bechtel
Oroville Reservoir, Dams and Power Plant, Including Contingencies, Engineering and Administration but without Interest During Construction	**$394,013,000**
Feather River Project Aqueduct	
Delta Cross Chanoel	$8,960,000
Intake Channel and Fish Protective Works	5,694,000
Pumping Plants No. I, II-A, and II-B	105,755,000
Aqueduct—Pumping Plant No. I to San Luis Creek	43,771,000
San Luis Dam and Reservoir—Including Forebay	84,974,000
Afterbay Modification at San Luis Dam	
Afterbay	9,956,000
Penstock Modification	5,127,000
Aqueduct—San Luis Creek to Wheeler Ridge	112,359,000
Pumping Plants No. III, IV, and V	56,639,000
Pumping Plant No. VI	65,828,000
Buena Vista Forebay	2,724,000
Aqueduct—Wheeler Ridge to Quail Lake	78,762,000
Quail Lake Forebay	8,882,000
Aqueduct—Quail Lake to Ridge Basin	47,837,000
Ridge Basin Power Plant	27,166,000
Ridge Basin Afterbay	2,465,000
Aqueduct—Ridge Basin to Castaic Creek	28,378,000
Castaic Power Plant	40,581,000
Castaic Creek Dam and Reservoir	14,934,000
Castaic Reservoir to Granada Reservoir	36,753,000
Granada Reservoir	12,763,000
Alameda Branch—Aqueduct	28,255,000
Alameda Branch—Dams and Reservoirs	12,088,000
Alameda Branch—Relift Pump Plant	3,936,000
District Offices, Communication Systems, Service Roads, etc.	948,000
Subtotal	$845,535,000
Contingencies	136,577,000
Engineering and Administration	77,501,000
Interest During Construction, Oroville Dam and Aqueduct	88,933,000
Total cost	$1,542,559,000

The revised schedule of water deliveries for Route No. 8-A required increasing the aqueduct from San Luis Reservoir to the Kings-Kern County line from 7,000 cfs. to 8,000 cfs. In order to operate Pumping Plant No. III on an off-peak basis, its capacity and the discharge aqueduct capacity were increased from 600 cfs. to 800 cfs. Comparative cost estimates for Routes No. 8-A and 10-A are shown in Tabulations III-O and III-P respectively.

FACILITIES FOR UPPER FEATHER RIVER SERVICE AREA

General Description

The upper Feather River development as proposed in the report of the State Engineer for inclusion in the Feather River Project, comprises developments on the North Fork, Middle Fork and South Fork of the Feather River. This development is not presently included in the Feather River Project or cost estimates thereof.

The North Fork development includes three dams and reservoirs on upper Indian Creek and its tributaries intended to stabilize stream flows for improved fish life, provide resting places for wild fowl, develop a recreational area for summer vacationists, and two of the developments would provide supplemental water for irrigable lands in Indian Valley.

The Middle Fork development consists of two dams for the purpose of impounding water for domestic and recreational uses as well as for irrigation.

The South Fork development represents the bulk of the Upper Feather River Project as proposed by the State Engineer, and includes storage and diversion dams, tunnels, power plants and canals. The purpose of this development is to supply irrigation water to the Oroville-Wyandotte Irrigation District and to lands in the Yuba County area. The proposed power developments are a source of revenue and as such would help defray the cost of irrigation water thereby making the whole project more economical.

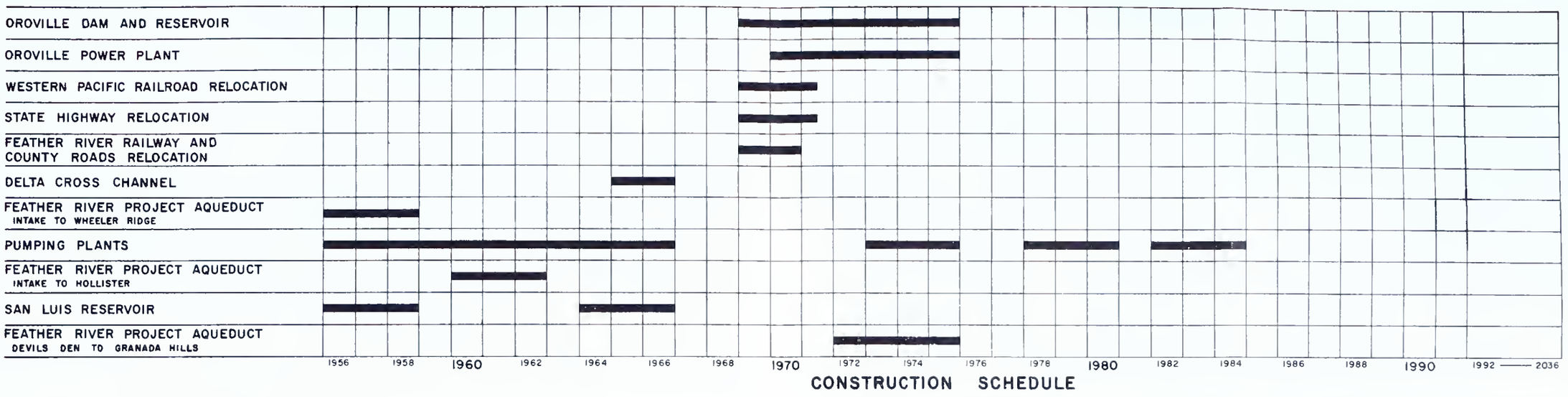
Scope of Work Reviewed and Methods Employed

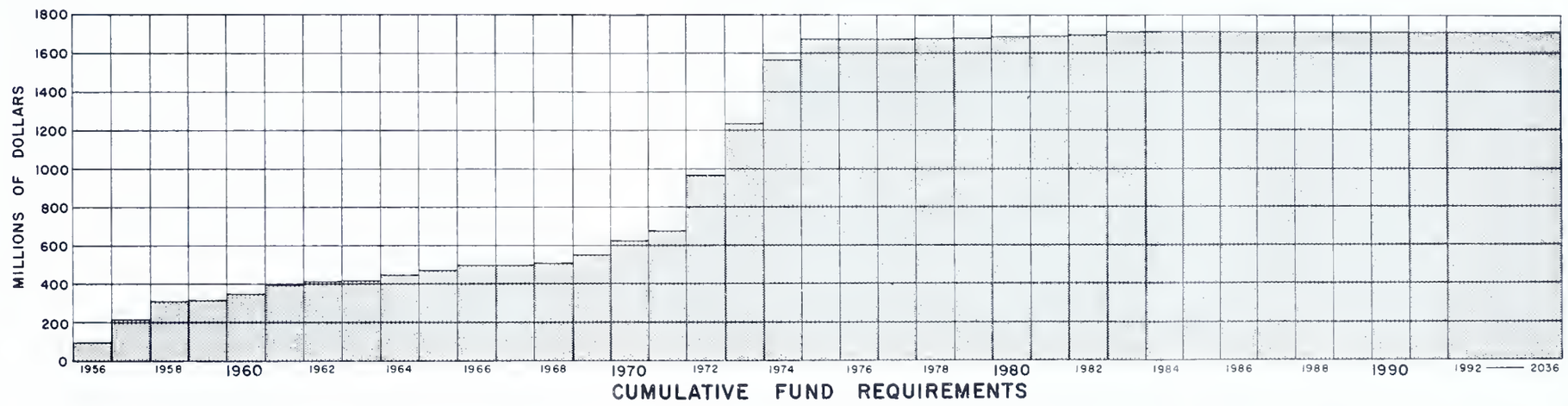
The proposed developments on the North and Middle Fork lend themselves logically to consideration as one unit and the South Fork projects as a separate entity.

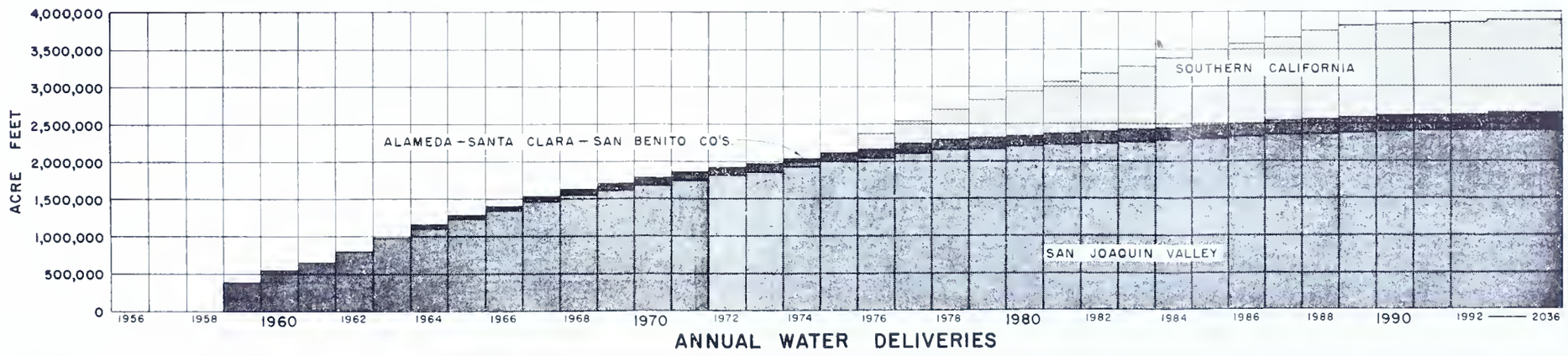
The scope of the North and Middle Fork developments, comprising five dams and reservoirs is given in the table on the following page.

The analysis of the North and Middle Fork developments consisted principally of a review of preliminary plans and estimates presented in the State Engineer's Report. Design of the dams was checked, and quantities and estimates were independently arrived at.

The more extensive South Fork developments constitute an integrated system consisting of two storage

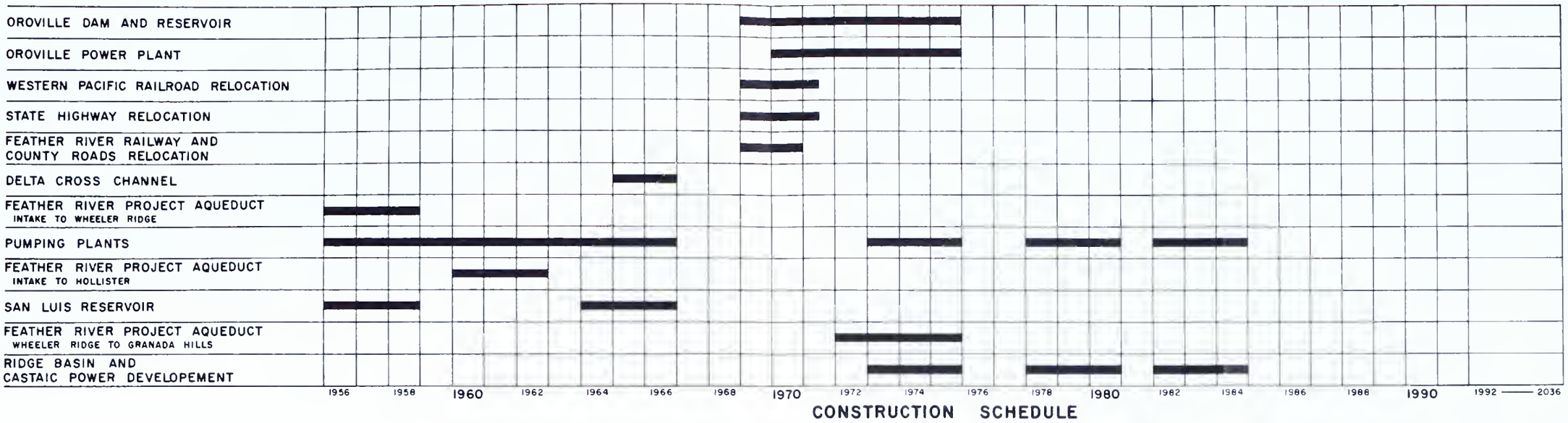

CONSTRUCTION ITEMS
OROVILLE DAM AND RESERVOIR
OROVILLE POWER PLANT
WESTERN PACIFIC RAILROAD RELOCATION
STATE HIGHWAY RELOCATION
FEATHER RIVER RAILWAY AND COUNTY ROADS RELOCATION
DELTA CROSS CHANNEL
FEATHER RIVER PROJECT AQUEDUCT INTAKE TO WHEELER RIDGE
PUMPING PLANTS
FEATHER RIVER PROJECT AQUEDUCT INTAKE TO HOLLISTER
SAN LUIS RESERVOIR
FEATHER RIVER PROJECT AQUEDUCT DEVILS DEN TO GRANADA HILLS
1956 1958 1960 1962 1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 — 2036
CONSTRUCTION SCHEDULE

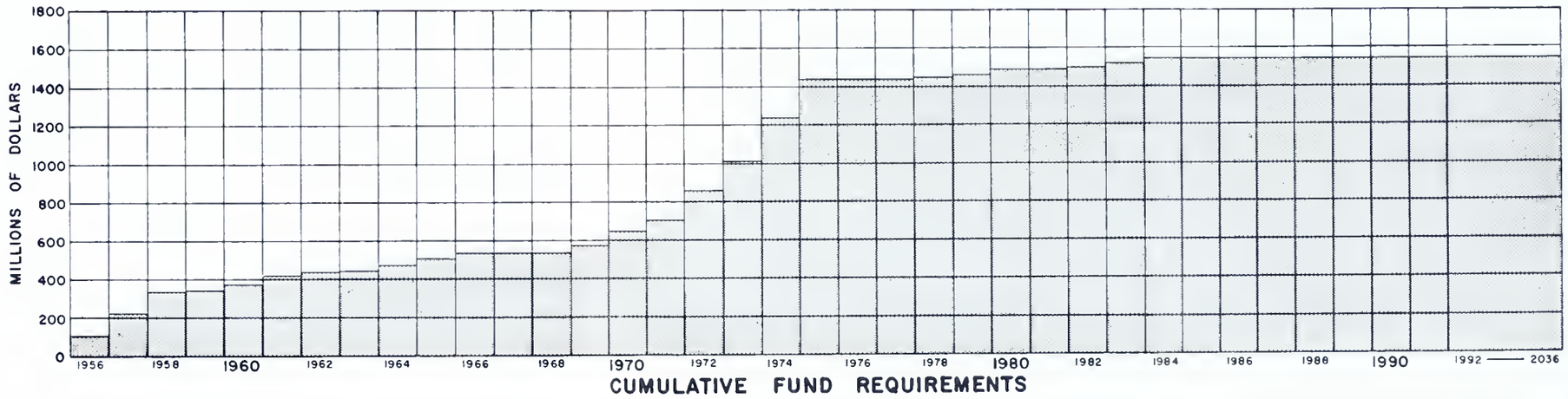


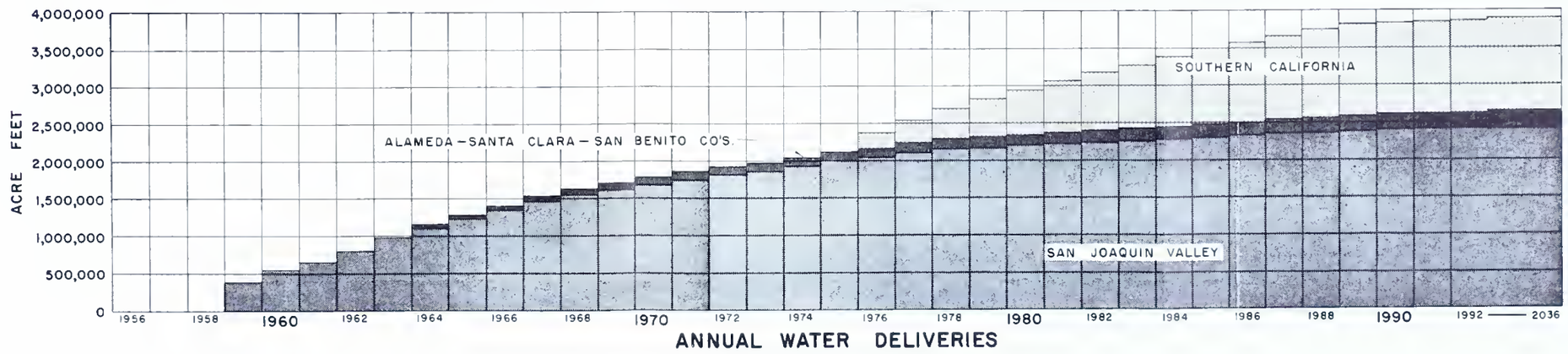


FEATHER RIVER PROJECT — CONSTRUCTION PROGRAM — ROUTE 8A

PLATE III-F


CONSTRUCTION ITEMS
OROVILLE DAM AND RESERVOIR
OROVILLE POWER PLANT
WESTERN PACIFIC RAILROAD RELOCATION
STATE HIGHWAY RELOCATION
FEATHER RIVER RAILWAY AND COUNTY ROADS RELOCATION
DELTA CROSS CHANNEL
FEATHER RIVER PROJECT AQUEDUCT INTAKE TO WHEELER RIDGE
PUMPING PLANTS
FEATHER RIVER PROJECT AQUEDUCT INTAKE TO HOLLISTER
SAN LUIS RESERVOIR
FEATHER RIVER PROJECT AQUEDUCT WHEELER RIDGE TO GRANADA HILLS
RIDGE BASIN AND CASTAIC POWER DEVELOPEMENT
1956 1958 1960 1962 1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 — 2036
CONSTRUCTION SCHEDULE



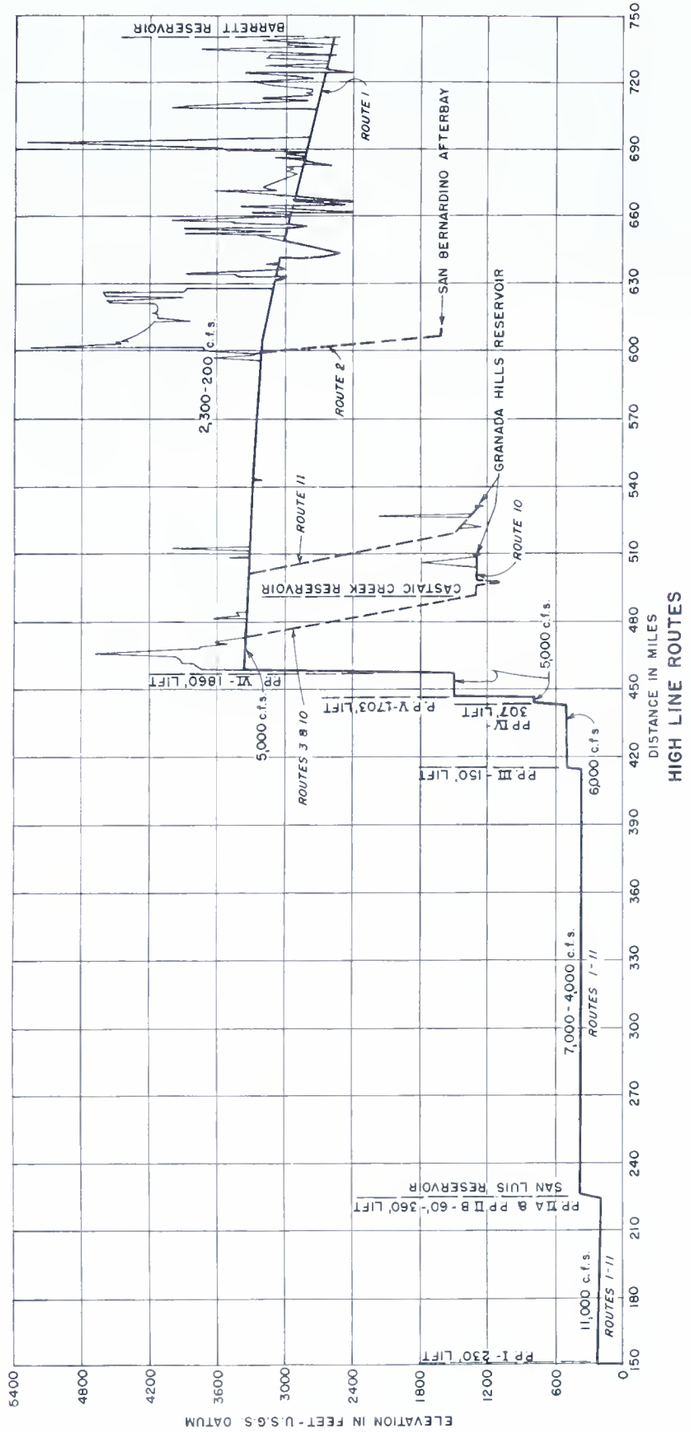


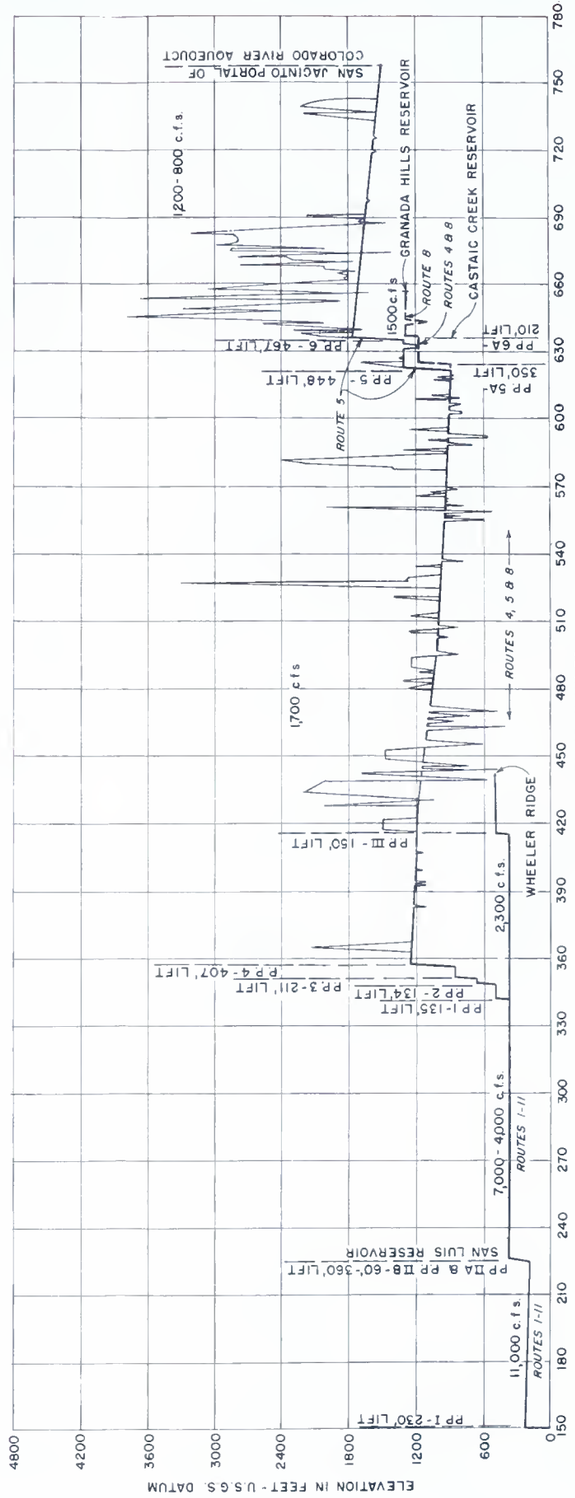
FEATHER RIVER PROJECT — CONSTRUCTION PROGRAM — ROUTE 10A

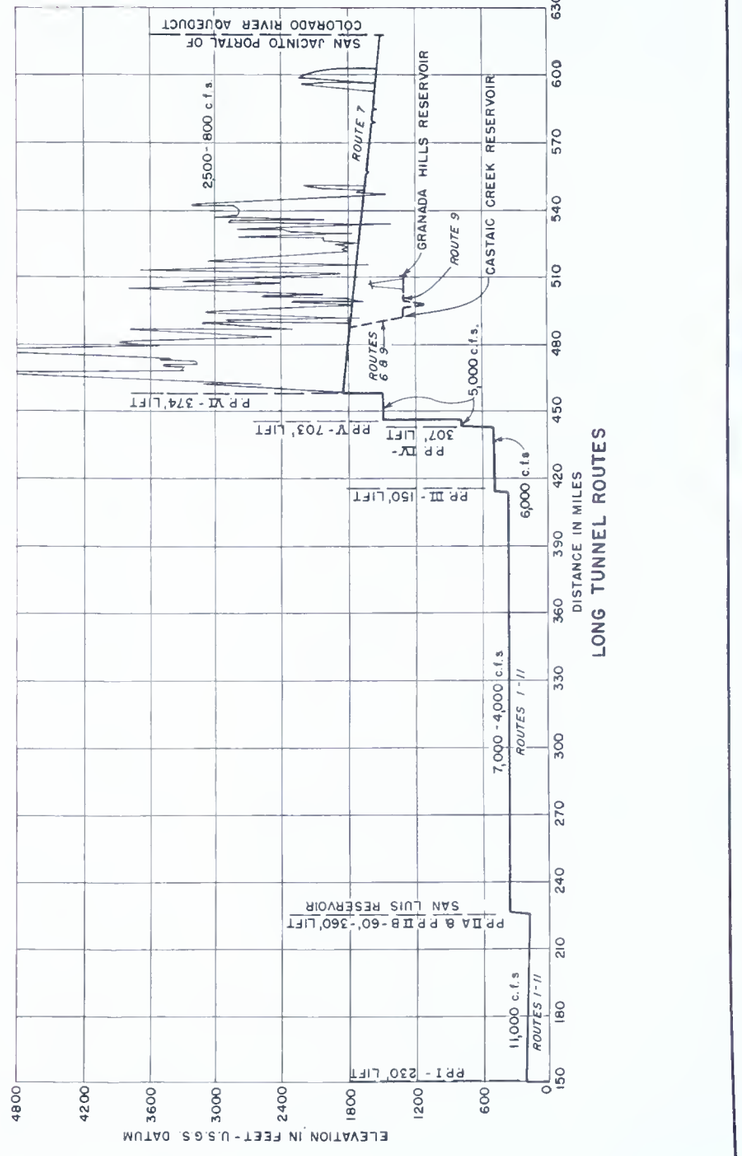
PLATE III-G

PROFILES - ALTERNATE ROUTES
FEATHER RIVER PROJECT

BECHTEL CORPORATION







NORTH AND MIDDLE FORK DEVELOPMENTS

Name and location	Description	Function	Storage capacity acre-feet	Capital cost (State estimate)	Cost per acre-foot stored
Antelope Valley Reservoir on Indian Creek	Impervious earth fill dam 75 feet high with side spillway	Stream regulation for wild life improvement and supplemental irrigation water for Indian Valley	18,200	$380,000	$20.85
Dixie Refuge Reservoir on Last Chance Creek	Zoned earth fill dam 50 feet high with side spillway	Stream regulation for improvement of wild life and recreation	14,300	420,000	29.40
Abbey Bridge Reservoir on Clover Creek	Zoned earth fill dam 100 feet high with side spillway	Stream regulation for wild life improvement and supplemental irrigation water to Indian Valley	8,400	730,000	87.00
Grizzley Valley Reservoir on Big Grizzley Creek	Zoned earth fill dam 90 feet high with side spillway	Stream regulation for wild life improvement and recreation plus domestic and irrigation supply to the Mohawk Valley	49,000	398,000	8.12
Frenchman Reservoir on Little Last Chance Creek	Zoned earth fill dam 98 feet high with side spillway	Regulated water supply for irrigation in the Sierra Valley	30,000	717,000	23.90
Total Capital Cost of North and Middle Fork Developments				$2,645,000	

dams, five diversion dams, six tunnels, two power plants, and canals for the purpose of delivering irrigation water to the Oroville-Wyandotte Irrigation District in Butte County. The system is designed to supply irrigation water to Yuba County should such a demand develop at a future date. Details of the South Fork features are given in the following table.

Available preliminary data supplemented by field information obtained by Beehtel representatives was used as a basis in reviewing proposed South Fork developments. Project requirements were discussed with officials of water districts and other interested persons to obtain their considered views.

General Comments

The construction of North and Middle Fork facilities as proposed is considered to be feasible but economic justification is dependent upon public policy

SOUTH FORK DEVELOPMENTS

Name and location	Description	Function	Storage capacity acre-feet	Capital cost (State estimate)	Cost per acre-foot stored
Little Grass Valley Reservoir on South Fork	Zoned earth fill dam 176 feet high	Storage and stream flow regulation	50,500	$2,992,000	$59.30
South Diversion Dam and Tunnel on South Fork	Concrete diversion dam 70 feet high diverting via 13,900 feet of 7 ft. lined tunnel to Lost Creek Reservoir	Diversion of water from South Fork to Lost Creek Reservoir	Nominal	2,286,000	
Canyon Creek Diversion Dam and Tunnel on Canyon Creek	Concrete diversion dam plus 22,400 feet of 7 ft. tunnel, mostly unlined to Slate Creek	Diversion of water from Canyon Creek to Slate Creek	Nominal	2,390,000	
Slate Creek Diversion Dam and Tunnel on Slate Creek	Concrete Diversion dam plus 11,500 feet of 8.5 ft. lined tunnel to Lost Creek Reservoir	Pick up water transported from Canyon Creek, divert this and additional water from Slate Creek and transport to Lost Creek Reservoir on Lost Creek	Nominal	2,957,000	
Lost Creek Reservoir and Afterbay on Lost Creek	370 feet high zoned earth and rock fill dam immediately downstream of the existing Lost Creek arch dam with outlet works and afterbay	Storage and regulation for release to downstream power plants and irrigation works	140,000	16,123,000	115.20
Woodleaf Tunnel and Power Plant on South Fork	47,000 kw installed capacity power plant at the terminous of 16,600 feet of 8.5 ft. lined tunnel	Transport water from Lost Creek afterbay to Woodleaf Power Plant, generate power and release for downstream use		10,158,000	
Forbestown Diversion Dam, Tunnel and Power Plant on South Fork	Concrete diversion dam, 18,340 ft. of 8.5 ft. lined tunnel and a 28,000 kw installed capacity power plant	Pick up water from Woodleaf Power Plant discharge plus additional water from South Fork, divert into tunnel to Forbestown Power Plant, generate power and release for downstream use	Nominal	8,558,000	
Ponderosa Dam and Afterbay on South Fork	Concrete arch dam 120 feet high with outlet works and afterbay	Diversion of irrigation water into the Miner's Ranch Conduit system	Nominal	1,366,000	
Miner's Ranch Conduit on South Fork	Conduit for 125 cfs. capacity consisting of 6 miles of canal, 1.5 miles of flume and 4.4 miles of tunnel	Transportation of irrigation water to the Oroville-Wyandotte Irrigation District Distribution System		3,403,000	
Miscellaneous	Improvement of facilities including Miner's Ranch Terminal Reservoir North Honcut Canal, Mt. Ida Canal, Bangor Ditch and miscellaneous	Improvement of existing Oroville Wyandotte Irrigation District facilities		775,000	
Total Capital Cost of South Fork Development				$51,008,000	

since no direct revenue will result from the features involved. Based on available preliminary information, the state design is considered sound and the structures appropriate for the intended uses. Quantities and estimates have been found to be reasonable.

The State Engineer's proposal for the South Fork development is based on very preliminary information but to the extent that the availability of basic data permitted, the scheme was checked and found to be satisfactory. Additional field investigation and preliminary design development will be required to confirm the effectiveness of proposed installations toward meeting project objectives. The state construction cost estimates are considered reasonable.

The State Engineer's plan calls for controlled release from Lost Creek Reservoir through energy-dissipating valves into an afterbay from whence the water enters the portal to the Woodleaf power plant tunnel or flows down the Forbestown irrigation canal.

Analysis of the State's proposed operation for the South Fork developments shows that this controlled release from Lost Creek Reservoir is under substantial head and that the installation of a small power plant is economically feasible.

It is recommended that further consideration be given to the following design elements:

Investigate Lost Creek Dam foundations to confirm that a dam of this height can be safely founded at the proposed location. A more careful determination of the source of suitable materials for the 4,994,000 cubic yards of fill for the dam also appears warranted.

The Slate Creek Tunnel capacity, based on data furnished, is approximately 400 cfs. whereas the design requirement is stated by the State as 500 cfs.

The State's Forbestown Tunnel cost estimate is based on a length approximately 1,000 feet shorter than the actual length shown on the plans.

The Miner's Ranch conduit is designed for 125 cfs. in the work proposed for initial construction. Included in proposed future work is a separate item for the enlargement of Miner's Ranch conduit for a flow of 250 cfs. It is suggested that the 4.4-mile tunnel section of this conduit be constructed in the initial stage to the full capacity of 250 cfs.

REVIEW OF FEATHER RIVER-SACRAMENTO RIVER CANAL

Introduction

The Feather River Project Report as prepared by the State Engineer includes a section that discusses the Feather River-Sacramento River Canal. The inclusion of this feature is pursuant to the language of the appropriation acts applicable to the Feather River Project studies requiring that the Division of Water Resources also investigate, survey and study * * * "a Feather River-Sacramento exchange canal north of Marysville Buttes in connection with the consideration by the Water Project Authority of a modification pursuant to Chapter 1441, Statutes of 1951, of the Feather River Project to include such a canal" * * *. This 16-mile long open canal would pick up water from the Feather River approximately 10 miles below Oroville Dam and run in a generally southwesterly direction to deliver water into Butte Creek, a tributary of the Sacramento River.

The State Engineer's Report states that this canal could be used for the purpose of coordinating operation of Oroville Reservoir with facilities of the Central Valley Project and to introduce Feather River water into the Sacramento River system; however, the report does not recommend its inclusion in the Feather River Project; nor is the estimated cost thereof included in the Feather River Program.

Scope of Work Reviewed

Available plans and estimates prepared by the State Engineer were reviewed to determine engineering feasibility, hydraulics, and accuracy of the estimates.

The proposed development consists of 85,700 lineal feet of unlined canal with side slopes of 1.5 horizontal to 1 vertical and with a bottom width of 18 feet. Slope of the canal is 0.3 foot per 1,000 feet. With an assumed roughness coefficient of 0.025, typical of an earth canal in a moderately maintained condition, and with the design flow of 750 cubic feet per second, the water velocity would be three feet per second. This is assumed to be a non-eroding velocity for the materials expected to be encountered.

The State Engineer's Report estimates an annual required diversion through this canal of 215,000 acre-feet. This is equivalent to 300 cubic feet per second of constant flow, hence, the ditch would be capable of delivering that annual diversion by flowing to capacity 40 percent of the time.

To maintain the non-eroding ditch grade and follow the ground profile thus maintaining the excavation at a minimum, the plans include five reinforced concrete drop structures providing a total of 27 feet of drop.

Other items included in the estimated work are four siphons, five bridges, an inlet structure, a diversion dam, and fencing. The purchase of right of way is also included in the total cost.

Of the $1,250,000 cost estimate, the canal excavation represents $416,000. This cost is reasonable, being 50 cents per cubic yard for the estimated 832,000 cubic yards of excavation, assuming no appreciable amount of rock will be encountered. This assumption is not supported by geological data but probably is reasonable, in view of the shallow cuts involved which average about eight feet deep.

Conclusions

The canal as outlined appears satisfactory as a preliminary design for the assumed diversion requirements.

Data upon which the estimate is based are very preliminary. Geologic studies and plans for the appurtenances must be made before realistic cost estimates can be made and economic justification of the project could be evaluated.

Further analyses of water rights and the effects of such diversions as would decrease the Feather River Project yields are necessary.

CHAPTER IV

PROJECT POWER

INTRODUCTION

Power and energy are very important aspects of the Feather River Project. Generated power may well be considered a by-product of the aqueduct project, but the power and energy required for the pumping plants on the State's proposed High Line Route when the project is in full operation are more than five times those produced by the Oroville generating plant. The values are:

	Demand power in kilowatts	*Energy in annual kilowatt-hours*
Pumping plants	2,400,000	9,272,000,000
Oroville Generating Plant	440,000	1,720,000,000
Calculated deficiency	–	7,552,000,000

Thus, the net power situation resolves itself into a large requirement for power, and no matter how the hours of pumping might be distributed with regard to hours of generation, there is an energy deficiency which must be made up from some additional power supply.

The large power and energy deficiency is considered in the State's Report to be best made up by power purchased from the Pacific Gas and Electric Company. Purchasing off-peak power for all of the pumping plants except Nos. 1, II-A, II-B and Relift after completion of the project, has a net dollar advantage annually over the purchase of continuously supplied, that is on-peak, power when based on the estimated rates quoted in the State's Report.

CONCLUSIONS

The conclusions reached from an examination and study of the power features of the Feather River Project are summarized below.

The basic power scheme is a feasible plan for handling the electric power requirements and hydro-electric generation.

The power loads for pumping greatly exceed the Oroville generation and the deficiency must be made up either by purchasing power or by constructing a power generation and transmission system. Constructing a power system has the disadvantage of not only requiring greater capital investment, but also gives no promise of affording any annual savings over the presently estimated rates for purchased power.

The load demand requirements of the pumping plants are well within the capability of the utility company system when the latter is projected at the same rate as Federal Power Commission growth estimates.

The optimum power plan consists of (1) selling all dependable hydro power during on-peak hours so as to realize highest revenue of about 8 mills per kilowatt-hour, and (2) purchasing as much power as possible at off-peak hours to get lowest net rates of about 4 to 5 mills per kilowatt-hour. Although designing the system to use as much off-peak energy as the hydrology permits involves extra capital investment, the annual energy cost savings soon recover the extra investments and this plan of procedure consequently reduces total annual charges.

The market for generated dependable power is now a favorable one and it can be expected to continue so.

The lower cost of off-peak purchased power and the higher value of generated on-peak power are due to the characteristics of the already established loads on the power system. These power value relations can be expected to continue as long as no radical change takes place in the utility system load characteristic, which is typified by the demand curve having a daily cyclic variation with peaks and valleys, and week-end values which are predominantly of the valley characteristic.

It is a distinct economic advantage, where hydrology permits, to build pumping plants with sufficient capacity to limit purchased power to off-peak rates. Where water storage and flow limitations prevent this for the ultimate installation, as at Plants 1, II-A and II-B, off-peak operation should be followed as long as possible during the step construction years at these plants.

Because of many variable project factors which will affect and determine the actual power requirements as well as the most advantageous manner of meeting them, it is advisable as the project progresses to make careful and complete estimates of power requirements for several years in advance. Power contracts and power scheduling must generally be arranged years in advance.

The kilowatt capacity of generation at Oroville, as well as at any drop plants as included in certain of the proposed modified routes, should be finalized only after (1) water flow values have been firmly established based on analysis of a series of test years, (2) power rates have been more firmly established for each hydro-electric plant location, and (3) the optimum amount of installed capacity and dependable capacity has been calculated.

The primary purpose of Oroville Dam will be to firm up the supply of water in the Delta for the project. Equitable allocations of costs should be made for benefits due to flood control, irrigation, urban water supply, navigation and power. The hydro power being a by-product materially assists in paying annual charges for irrigation and urban water supply.

The economy of using off-peak power is rather clearly established for Pumping Plants III through VI. However, for Pumping Plants I, II-A and II-B there is considerable on-peak use contemplated, and this can be decreased by modification of the State's operating plan as discussed in Chapter III of this report.

A consolidated power program should be developed and carried out in which purchased power contracts for all pumping plants are integrated with power sales, when applicable, from the project hydro-plants.

OPTIMUM OF POWER

The power required can be most economically supplied by (1) buying most pumping power at low off-peak rates, and (2) selling all generated power at the higher on-peak rate for dependable power. Such a method is proposed in the State Report because of annual cost advantages. Basically, it is a sound and favorable method since it is based on actual rates and market values that have already been established by existing loads throughout the area. In other words, the law of supply and demand has operated to bring about a variation in power value depending upon the hours of the day or week during which power is taken. Such off-peak power is available now from existing steam plants, and will be available in future years, as the off-peak pumping loads increase, from the utility system's necessary expansion to meet their other load growth as discussed herein.

POWER LOADS

Pumping Plant Load Values

The pumping plants have the estimated capacities listed below. These listed values exclude the spare unit capacities at Plans IV, V and VI, and are for ultimate operation in and after 1991. The kilowatt values are approximate plant input values based on motor nameplate ratings and allowing for losses.

Pumping plant	*Plant kw.*	*Plant c.f.s.*
I	265,000	11,000
II-A	215,000	8,000
II-B	246,000	8,000
III	95,000	6,000
IV	162,000	5,000
V	366,000	5,000
VI	1,034,000	5,000
Relift	17,000	350
	2,400,000	

The energy and power values for the State's proposed High Line pumping plants, all located in P. G. & E. service area, are plotted on the accompanying curve sheet. Figure IV-A shows annual pumping energy in billions of kilowatt-hours for the years 1950-2000, also for comparison purpose the estimated energy for the Federal Power Commission's Region VIII which covers essentially California, Nevada, and Arizona. The Region VIII estimate is based on projection of Federal Power Commission estimates for 1960-1980. The pumping plant curve is the energy requirements estimated for pumping, as given in the table on page 50 of the State's Report. The FPC estimated energy requirements for Region VIII by 1980 are 190 billion kilowatt-hours, whereas the pumping plant energy requirements in the same year are 4.95 billion kilowatt-hours, which is 2.6 percent of the regional total. Similarly, following projection of the FPC estimated increase in annual energy to 1980 on to 1991, the requirements for Region VIII would total 290 billion kilowatt-hours and the pumping plant annual energy requirement of 9.27 billion kilowatt-hours under full operation would represent only 3.2 percent of the regional total.

Peak demand values in millions of kilowatts are shown in Figure IV-B. The FPC Region VIII estimated demand for 1980 is 36 million kilowatts. We have assumed that the P. G. & E. Company's growth rate will at least increase at the same rate as the FPC has estimated for this region, and based upon the P. G. & E. peak for August, 1955, their demand will be about 15 million kilowatts in 1980. The project pumping plant demand of 1.4 million kilowatts, based upon installed capacity in 1980, would be only about 9.5 percent of P. G. & E.'s estimated peak.

FIGURE IV-A
ANNUAL ENERGY

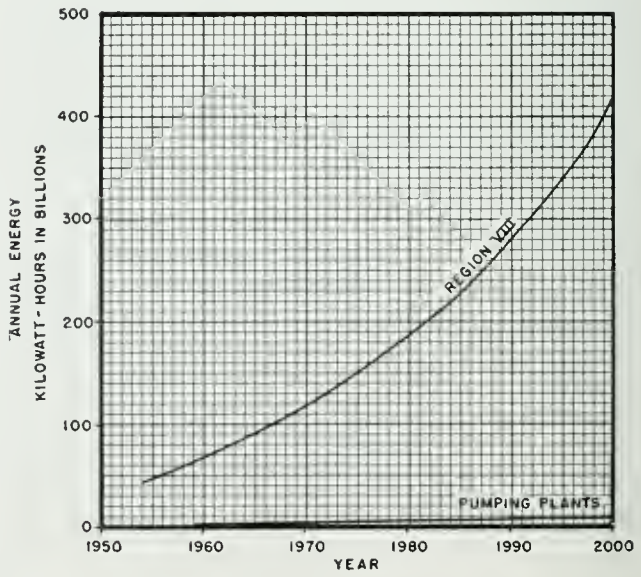
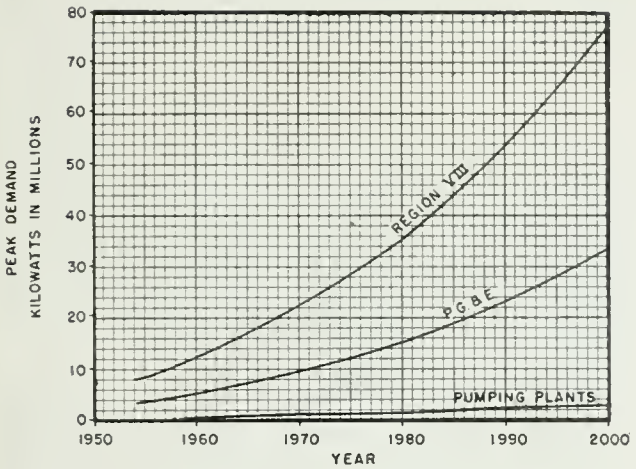


FIGURE IV-B
POWER DEMAND



The pumping plant demand reaches 2,400,000 kilowatts in 1991, based on full capacity being installed in all pumping plants by that time. The projected FPC Region VIII estimated demand for 1991 is 56,000,000 kilowatts, and the demand projected for Pacific Gas and Electric Company is about 24,000,000 kilowatts. Load demand of 2,400,000 kilowatts for the eight pumping plants in 1991 is only 10 percent of the P. G. & E. Company estimated peak, and is 4.3 percent of the Region VIII estimated peak for the same year.

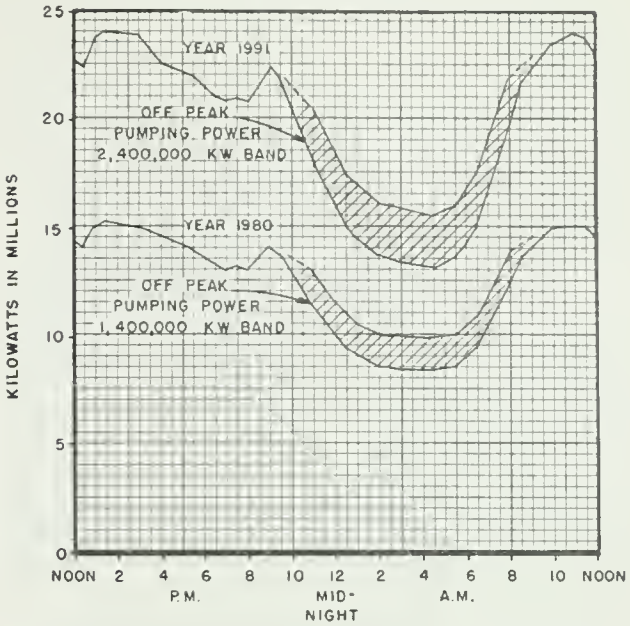
Another load relation is the typical weekday load illustrated by the accompanying Figure IV-C for the years 1980 and 1991. This figure shows projected summer weekday loads based on existing daily loads. The off-peak pumping power loads that might be expected are indicated by the shaded areas. Thus for 1980, Figure IV-C shows a 1,400,000-kilowatt band from 11 p.m. to 8 a.m., the likely off-peak pumping hours. Similarly, the curve for 1991 shows a 2,400,000-kilowatt band. In the year 1980 the daily load demand dips from 15 million kilowatts to 8.5 million kilowatts, leaving in an average day about 7.5 million kilowatts of unused capacity available to meet the pumping demand of 1.4 million kilowatts. In the year 1991 the daily load demand dips from 24 million kilowatts to about 13 million kilowatts, leaving about 11 million kilowatts of unused capacity to meet the pumping demand of 2.4 million kilowatts. This demand would be only about 22 percent of the available unused capacity.

These comparisons indicate that it is well within reasonable limits of the projected growth and operation of the utility to supply the maximum power requirements of these pumping plants.

Off-Peak Pumping vs. Continuous Pumping

The cost of purchased power will be a minimum if pumping is entirely avoided during the particular

FIGURE IV-C
ESTIMATED TYPICAL DAILY LOAD CURVES



hours of the day and week when on-peak rates apply. This has been accomplished during the first fifteen years of operation by having sufficient pumping capacity, and corresponding reservoir and conduit capacity so that no on-peak pumping power is used at Plants I through VI. Relift plant uses on-peak pumping. In subsequent years, I, II-A, II-B, and relift use on-peak power because of water storage limitations, although III through VI are always confined to off-peak pumping power, which is very desirable.

The necessity of using some on-peak power for Plants I and II is based upon the limits placed on storage of water at Oroville and at San Luis Reservoir. By small but significant variations due to manipulations of water flow and storage ahead of Pumping Plant III, it is expected that small but worthwhile savings can be made in power costs for Plants Nos. I, II-A, and II-B.

For Pumping Plants III through VI, off-peak pumping is contemplated. The net cost advantage of off-peak pumping over continuous pumping is indicated by the following approximate cost relations for the ultimate development. While off-peak pumping initially takes approximately $100,000,000 greater capital investment, the annual power bill is $20,000,000 less and the resulting net annual savings are $15,000,000 after proper allowance has been made for interest on the larger investment.

Purchased Power Rates

For purchased power a favorable rate, that is, one of best advantage to the State, should be realizable. The cost of one kilowatt-hour can be expected to vary over a wide range depending upon where, at what

voltage, and what time of day or week it is used. This is to be expected because of the power utility system characteristics of usage factor and the relations between cost and usage factor. Generally, in any manufacturing operation the more nearly continuously and heavily equipment is loaded, the more units of product and the lower the cost per unit of product. Similarly, the charge for generating plants, transmission lines and substations per unit of electric energy is less if they are heavily used most of the time; that is, with operation at a high load factor. Most utility systems have loads and load peaks which result in much of the equipment being used only part time at full capacity. When loads, such as a pumping load, can be added at off-peak hours, as indicated in the daily load curves previously discussed, so as to increase the usage factor, the added power can usually be produced at a lower cost.

Using the proposed rates of P. G. & E. Company contained in the State's Report, we have the following typical values in mills per kilowatt-hour total energy charge representing combined demand plus incremental energy:

PUMPING PLANTS

	I, II	*III, IV, V*	*VI*
Off-peak rate			
Based on use of 4,610 hrs. per year, or 53 percent of time	3.32	3.85	3.91
On-peak rate			
Based on continuous use	6.43	6.83	6.97

The annual cost of power, using values from State Report, Table 19 (High Line Route), for all the pumping plants, divided by the State Report's values of annual electric energy requirements for pumping, results in an average cost in mills per kilowatt-hour ranging from 3.87 in 1959 through 1963 when all the pumping is off-peak, to 4.94 in 1991, when Plant I is on-peak and II-A and II-B are partially on-peak. This range of 3.87 to 4.94 mills per kilowatt-hour shows the predominance of off-peak pumping and the importance of operating off-peak.

POWER GENERATION

There is and will continue to be a growing market for electric power. Such a conclusion is reached from examination of the history of the power system growth in California. On a national average, the electric power industry has doubled in ten years, and there is no reason to doubt a continued growth and an increasing market for power.

Economy and Benefits of Generating Power

The generating of hydroelectric power at Oroville Dam is a seeming natural and logical step but, whether or not it is an economic step is dependent on charging a sufficient fraction of the dam costs to water regulation and delivery and to flood protection, to bring the power generation costs within competitive range. For example, considering the Oroville Reservoir, Dams and Power Plant combined cost of $418,661,000 from State Report, Table 1, and the installed capacity of 440,000 kw, the installed cost is $950 per kilowatt. This is many times the cost of a thermal-electric plant. For typical competitive hydroelectric plants, the cost would be expected to fall in the range $200 to $400 per kilowatt, or between $88,000,000 and $176,000,000 for the balance chargeable to power generation after benefits are deducted for municipal water supply, irrigation, and flood control. Consequently, the generation of power at Oroville should be considered a means of defraying only a part of the cost of the Oroville Dam.

Falling Water Hydro Power

The arrangement of selling the rights to falling water energy, instead of selling generated electric power, is one which has limited precedent, but which nonetheless may have acceptable attractions and advantages. The Pacific Gas and Electric Company has offered to purchase the rights to falling water energy of the Trinity River Project from the Bureau of Reclamation. Any such arrangement at Oroville Dam would decrease the capital expenditure by the State. Other continuing advantages, such as annual revenue from water energy and from taxes, in addition to lower capital investment, indicate that this arrangement of selling the use of the falling water might well be considered if proper conditions are set for scheduling water releases.

Amount of Dependable Generating Capacity

The operation of Oroville Reservoir through the period of lowest runoff, using water years from 1928 through 1934, forms the basis for sizing of Oroville hydroelectric generating plant. The installed capacity is stated as 440,000 kw., and the dependable capacity as 410,000 kw. Table 10 in the State's Report, "Suggested Schedule," gives kilowatt-hours per kilowatt of useful capacity for determining the magnitude of marketable power for Oroville.

In the possible modification of the Project High Line Route, reported upon in the State's Report, which in 20 years would include a 440,000-kw. Devil Canyon Generating Plant, or the State's other High Line Route modification involving two Castaic Creek power plants totaling 416,000 kw., there is indication that the installed or dependable capacities will not be on the best schedule in keeping with reservoir capacity and water flow in the conduit at these points in the aqueduct. Before the dependable capacity for such power drops can be accurately estimated and before the power revenue can be estimated within desirable accuracy, a more thorough analysis must be made based on established power rates and water flow conditions. This type of analysis has been carried out for the Oroville Power Plant and later, at the

appropriate design stage, should be carried out for any power drops that might become part of, or coordinated with, the Feather River Project, regardless of whether the energy is sold as electric power or as falling water in Southern California.

Generated Power Rates

The revenue computed by the State for the sale of generated power is based on estimated Pacific Gas and Electric Company rates. These rates were applied in the State Report in computing revenue for Oroville Plant, as well as for the possible Southern California Plant at Devil Canyon or those at Castaic Creek. These Southern California plants are in an area such that they might have revenues from Southern California Edison Company and it is therefore pertinent to note their expected rates, taken from November 4, 1955, correspondence to the State Engineer from Southern California Edison Company. Below are given rates for generated power, as computed from P. G. & E. Company estimates, and Southern California Edison Company estimates. In both cases a plant factor of 45 percent was assumed, and the value given is total for energy value plus dependable capacity value.

COMPUTED MARKET VALUE FOR GENERATED POWER FOR 45 PERCENT PLANT FACTOR ONLY

Based on P. G. & E. Co. Data

Point of delivery at 230 kv.,	*Oroville*
mills per kilowatt-hour	8.01

Based on Southern California Edison Co. Data

	Devil Canyon	*Castaic Creek*
Point of delivery at 230 kv., mills per kilowatt-hour	7.88	7.82

In the Bechtel financial calculations the revenue from Oroville is based on the P. G. & E. Company rates as given in the State Report, and the revenues for hydroelectric developments in Southern California are based on Southern California Edison Company rates as quoted in the reference letter as follows:

Dependable capacity	*Devil Canyon*	*Castaic Creek*
(per kilowatt per month)	$1.57	$1.55
Energy (per kilowatt-hour)	0.0031	0.0031

Miscellaneous Items for Later Study

There are many items which have not been evaluated or fully developed in the report and which deserve proper attention at an appropriate time in the planning and design of the project. The importance of some of these cannot be reliably established until more basic and detailed design work has been accomplished. Still other factors are known to be important, but their thorough investigation is not justified until the project leaves the preliminary-design stage and enters the working-design stage.

Among such items not yet evaluated or developed are:

Motor and pump starting.
Circuit breaker duty.
Combining pumping plants to reduce number.
Tax benefit evaluation for purchased power.

CHAPTER V

WATER DEMAND

INTRODUCTION

The State's Feather River Project report shows areas in California which could be served with water from the proposed project. It also indicates time schedules on which certain quantities of water could be delivered to these areas, and it shows, in its financial analyses, project income based on certain average revenues for the water delivered. The physical features of the project are designed, and their construction planned, for the purpose of meeting these water delivery schedules. The financial features of the project are planned to utilize income from the scheduled sales of water. It is therefore basic to the entire program that these water delivery schedules and revenues reasonably represent those which could be expected actually to prevail if the project is built.

Stanford Research Institute was retained by Bechtel to check the State Engineer's studies that led to their conclusions as to water delivery schedules and anticipated revenues as included in the Feather River Project Report. These matters were then immediately discussed with members of the Division of Water Resources assigned to such work on the subject report.

When it was ascertained that the schedules were not based on such economic studies of the proposed service areas, Stanford Research Institute was requested to make such studies to the extent possible in the limited time available in order that some reasonable conclusions could be drawn in these matters that so vitally affect the economic payout and financial aspects of the project.

The methods employed in the conduct of this study, its scope and limitations particularly due to the now original nature of so much of the effort, the basic assumptions adopted, the authoritative basic data researched, the material extent of field trips and discussions with local authorities, and the conclusions drawn thereon are comprehensively covered in the Stanford Research Institute Report to Bechtel. This report is included herein as Appendix "A."

This complication to our review that required developing much original data upon which to base conclusions as to economic feasibility, rather than initially verifying detailed material that had already been developed in the course of the formulation of the Feather River Project program by the Division of Water Resources, resulted in our decision to retain additional independent consultants especially qualified by long years of experience in the particular problems of California land use, irrigation requirements, and their related economic aspects. This section of our report will treat upon, but not duplicate, the extensive material embodied in the Stanford Research Institute's Report, which was done so commendably in a severely limited time. Herein developed are Bechtel's conclusions and recommendations relative to the economic aspects of the Feather River Project program.

SUMMARY CONCLUSIONS

On the following conclusions the Report of the State Engineer on the Feather River Project and Bechtel's position are in general agreement.

There is a demand for water within the areas proposed for service by the project which is adequate to furnish a market for all of the water the project will develop and deliver to its service areas.

Under present conditions this market can meet the prices for water required for irrigation in the San Joaquin Valley in the general range from $7 to $9 per acre-foot canal-side.

Urban demand in the South Coastal Area could meet prices for water required for such purposes in that area of $25 and even up to $45 per acre-foot canal-side.

Urban demand in the Alameda-Santa Clara-San Benito Area could meet prices representative of the costs of such delivery, in the general range of $17.50 to $22.50 per acre-foot canal-side.

GENERAL LIMITATIONS REQUIRING RECOGNITION

The Institute's Report stating the general limitations of the State Engineer's report data and their effect on any effort to review the conclusions regarding the water demand under the project are well expressed. The State Engineer's Report describes the physical features and estimated costs of a proposed project. It also shows a balance sheet between costs and revenues provided certain amounts of water can be sold at certain prices with a certain rate of increase in demand. There is little support in the State Engineer's Report for the assumptions on these items. The Institute has secured the additional information on these items that is available in the records of the State Engineer and the U. S. Bureau of Reclamation and based its review on these results and such independent studies as it could make in the time that was available.

Until the amounts of water to be served in each service area and a project policy on the price at which

water will be sold canal-side in each area have been established, realistic estimates of the time required for the demand to build up to the available supply cannot be made. Included in this need is the establishment of the policy which will be followed for the construction of the local distribution works in each area, particularly as to their financing. The cost of such local distribution systems may exceed the bonding capacity of undeveloped areas. The Report of the State Engineer merely selected certain physically available service areas and assumed prices which could be obtained for water. Until there are organizations established in these areas and commitments made for the purchase of project water, conclusions regarding demand are limited to potential needs which may be served by the project provided the terms and conditions of service are acceptable to the local units.

The limitations on present results relating to a market demand for water in the proposed Feather River Project are obvious. However, they have been omitted or overlooked in much past discussion, including to a considerable extent the report of the State Engineer. They have been mentioned here in order that it may be understood that all conclusions expressed in these comments are contingent on actual commitments to take and pay for project service on the terms proposed in the State Engineer's Report.

The Institute's Report divides its discussion of water demand for the different areas proposed for service. This is essential as conditions vary too widely for over-all averages to have meaning. The same division of areas has been followed in these comments.

WATER DEMANDS

San Joaquin Valley Service Areas

The Institute's Report discusses conditions affecting the project water demand in the San Joaquin Valley Service Areas. These are the areas proposed for immediate service on which the returns from water sales in early years of project operation will be required to carry much of the project financial load. These comments follow the sequence of the discussion in the Institute's Report and conclude with an estimate of the market for water in the San Joaquin Valley that can be expected in the first 20 years of operation.

The institute recognizes the need for considering land quality in selecting areas for service and in estimating water demand at any given price for irrigation water. This recognition is fundamental. It was not fully recognized in the determination of the potentially irrigable areas in Bulletin 2 of the State Water Resources Board. The Feather River Report of the State Engineer recognizes it only to the extent of including enough surplus land in the proposed areas of service to leave a net demand for good land sufficient to use the assigned water supply.

There is a variety of land classifications in use. These usually grade land as Class 1, 2, 3, etc. However, the same numbers in the different classifications do not necessarily represent the same results. The distinctions in the different classifications are more apparent than real. All agree in segregating the better from the poorer lands and recognizing the actual differences in crop production and capacity to pay for water. The essential item is to recognize that the classification of land for inclusion in the high cost projects now being proposed must be made more carefully than was needed in the earlier lower cost projects and that the poorer lands cannot meet the costs now required.

The institute found 388,000 acres that should not be included in the project in the total proposed service area of 1,549,000 acres, and that about one-half of the Semitropic Ridge area is capable of irrigation. They have divided the irrigable area between that now irrigated and that now unused but capable of irrigation. This classification is essential to an estimate of the rate of growth of water demand. Bechtel accepts these as a suitable basis for present estimates.

All land classifications of the potentially irrigable lands in the upper San Joaquin Valley are in agreement that there is more than enough land of good quality to represent an irrigation demand for more water than the State has assigned to this area in the Feather River Project. Differences in quality of land will affect the selection of the areas to be served and this selection will be reflected in the costs of the local distribution system for their services.

In the discussion of the "Water Balance and Overdraft Situation" in the Institute's Report, the results used by the State Engineer and the U. S. Bureau of Reclamation are presented and compared. For the West Side area the material relating to the present ground water supply is that used by the State Engineer and the U. S. Bureau of Reclamation. Both use the results in the report of the Ground Water Branch of the U. S. Geological Survey entitled "Ground-Water Conditions in the Mendota-Huron Area" of June 1954.

There is essential agreement regarding the extent of the present draft, present ground water supply and the resulting overdraft. The U. S. Geological Survey found that the original ground water in this area was limited to a small recharge from the west and some movement from the east into the lower portion of the West Side area. Under the lowering of the ground water in this area in recent years the ground water slope from the east now extends under much of this West Side area. This has caused an induced or secondary supply from East Side sources which it is estimated is now about 200,000 acre-feet per year. This

induced supply is correctly credited in present ground water balances in this area.

The State Engineer and the U. S. Bureau of Reclamation in their plans for this area propose to restore the ground water elevation so that the slope which now induces this inflow will be reversed. It is planned to remove drainage water from the West Side area from its eastern slope. To produce such drainage, ground water from the east side would encounter an adverse grade when it reached the eastern side of the West Side area. Under the proposed conditions the full needs of the West Side area will have to be met from project sources without assistance from ground water movement into the area from its eastern side. Inflow of ground water from the east might be continued if pumping for drainage is operated to produce a ground water trough within the West Side area far enough to the west to furnish an area of use for such eastern inflow on the east side of such a trough. The complications involved in such an operation are too great for the continuance of an induced ground water inflow to be relied upon under permanent project conditions. Such induced inflow will continue during the early years of project operation until the permanent ground water conditions planned under project operation have been established.

The project of the State Engineer does not include the construction of any such local works all service is to be on a wholesale basis with delivery at main canal side. The U. S. Bureau of Reclamation is building a concrete pipe distribution system for the Shafter-Wasco Irrigation District at an estimated cost of $273 per acre of gross area. The report of the U. S. Bureau of Reclamation on the San Luis Unit of the C. V. P. includes an estimated cost of $129,748,000 for a concrete pipe distribution system for 458,000 irrigable acres. This is an average cost of about $280 per acre. The annual costs of water for the Shafter-Wasco Irrigation District exclusive of payment for C. V. P. water will be of the order of $5 per acre-foot and about $15 per acre. Such costs are additional to those which would be paid to the State under its proposed Feather River Project.

The general assumptions made by the institute on which its analysis of the ability to pay are those generally used in such studies. Definite assumptions have to be made if definite answers are to be secured. The definiteness of the assumptions made, however, should not carry an implication that the results are similarly definite. An analysis based on costs and returns in these areas in recent years may not be applicable in the future unless the recent conditions and trends continue.

The rapid development of pumping from wells in this area, even under a known rapid rate of ground water lowering, has been profitable under the federally supported crop price for cotton. Profit in cotton production has depended on this support. The area limitations now in effect result in an essentially different position for lands with cotton history and for an undeveloped area lacking such a history.

In the results of the institute's analysis of ability to pay, Class 3 land is eliminated as lacking the production to meet proposed costs. This conclusion is considered sound.

The net farm income before water costs per acre-foot, in Table VI of the institute's report is before costs for the purchase of project water and for its local distribution, and their report states that distribution costs might equal water prices at canal side of $7 to $9 per acre-foot. Distribution systems, pipe type, may cost $200 to $300 per acre. The State Engineer proposes no state or other aid on these costs. The local irrigation districts, as now proposed, would have to construct such distribution systems with finances secured by district bonds sold in the open market. Annual interest and amortization on such bonds would probably exceed 5 percent per year or $10 to $15 per acre. Operation costs for such pipe systems might run $2 to $3 per acre per year. For farm delivery demands of about $2.75 acre-foot per acre, these costs represent about $4.50 to $6.50 per acre-foot. This would make the total cost of water to the landowner at his land, including payment to the State, from $12 to $14 per acre-foot or about one-half of the estimated net farm income resulting from the use of the water.

In some past practice it has been a sort of rule of thumb that an irrigation project could not collect from its landowners more than about one-half of the net return resulting from the use of the water. The conclusion of the institute that Class 1 and 2 land will be "a feasible economic venture" is believed to be as good an estimate as can be made with the use of past results and an attempted forecast of the future conditions. It should be emphasized again that this conclusion is open to much uncertainty and that estimates of project revenue should be conservatively made, particularly in regard to the amount of sales at these prices which can be made in the early years of project operation. It should be remembered that there has been no irrigation project in the San Joaquin Valley which has had costs for water of the amount that will be required here.

The unit water requirements as discussed in the institute report are based on the results of the State Engineer and the U. S. Bureau of Reclamation which are in generally close agreement.

No detailed review of these results could be made in the time available. There is now extensive experience in the San Joaquin Valley supported by records of the use of water. The various studies on water requirements that have been made over the past 30 years

have varied in their details but not widely in their numerical results. The results in the institute's report are accepted for present project planning use. Reliance can be placed on project operations conforming reasonably closely with these results.

The institute also discusses experience in the rate of development in other projects. It is stated that the Madera-Friant-Kern Canal of the Central Valley Project will deliver its ultimate volume of supplemental water after a five-year period of development. While this part of the Central Valley Project will have a market for 1,400,000 acre-feet in 1956, if it is available, this market will include interim sales to areas not having long term contracts. Such areas have bought Central Valley Project water in excess of demands of contract units whenever it has been available. Such purchases are at the $1.50 per acre-foot price and are used on areas already having distribution facilities. The contract units generally have 15 years to reach their full demand. Some of these units are taking excess water to build up their depleted ground water. Such purchases at $1.50 per acre-foot are not a criterion for similar purchases in the Feather River Project service areas at $8 per acre-foot used in the State Report analyses.

Table IX of the institute report presents their estimate of the demand for project water for irrigation in the San Joaquin Valley divided into the main service areas. This is stated to be based upon the maximum potential growth in water requirements. These can best be discussed by separate areas.

In Table IX all areas now irrigated are estimated to reach 80 percent of full demand in five years and full demand in eight years. Undeveloped lands are all estimated to reach 55 percent of full demand in five years and full demand in 13 years. For both areas combined the total demand at five years is 67 percent and the full demand is reached in 13 years.

There are no present distribution systems in any of these areas. As farms are generally large some portions of such present farm systems may be usable in the lateral systems of the local project units. However, all local units will need to construct distribution systems under the present state plan. These may have an average cost of about $300 per acre. The developed areas will have immediate crop returns to furnish security for meeting bond costs for such systems. However, this will be a relatively high bond issue per acre for the San Joaquin Valley and the units will also have high price contracts for the purchase of project water. Bond interest rates will probably reflect these conditions. Interest rates of 4 percent are as good as may be obtainable on such local bonds for developed areas.

For undeveloped areas there is little present assessed value behind any local bond issues and, if saleable, they will require higher interest rates. This will increase the cost burden in early years and may result in development in smaller units spread over a longer period of time. To date the plans for the Feather River Project do not include any provisions for constructing local distribution systems as a part of the project nor for financial aid to local districts for their construction.

The comments on the results in the institute report on a water delivery schedule that can be expected and on which the financial plans of the project should be based, can be best made by separate areas.

Table IX of the institute's report gives an irrigation demand of 805,000 acre-feet for land now irrigated and 205,000 acre-feet for undeveloped land in Fresno County.

The Fresno County area is now listed as 80 percent irrigated. The investment in these lands and their present production may enable them to finance their local distribution systems. These lands have cotton history and can continue to grow cotton on the present acreage. This area should make the most rapid use of water of any of the service areas. It would be the area first reached with project delivery. It should come nearer realizing the forecast in Tables VIII and IX of the institute's report than any other area. Its use represents nearly one-half of the total estimated for the entire San Joaquin Valley service area. It is considered that the estimated rate of use in Tables VIII and IX is somewhat optimistic but that it may be approached and perhaps reached. The results of the institute in its Tables VIII and IX are stated to represent their conclusions on the maximum potential growth in water development.

Kings County is similar to Fresno County except that only 30 percent of the total area is now developed. The King County area has a corresponding limited amount of present assessed value to secure district bonds. It cannot be expected to develop the use of water as rapidly as the Fresno County area. A more realistic estimate is considered to be a total use of 50 percent in five years, 75 percent in 10 years and full use in 15 years.

The Antelope Plain area is practically undeveloped. All costs of local distribution systems would have to be incurred by local taxing districts having almost no present surface value. There is extensive oil development in this area. No maps are at hand showing the extent of ownership of land by those whose interest is in the oil rather than crops. Either a form of district would be required under which only the surface title would be security for district bonds, or the oil owners would be expected to oppose a district in which their oil values stood behind a new irrigation project. Present resident voters are largely those employed in the oil industry. The Antelope Plain at present does not have wells and pumping plants except in limited areas. In addition to the cost of distribution systems

to use project water the landowners will have to incur the cost for wells and pumps if they are to recover deep percolation losses from project use.

The ground water in the Antelope Plain is of poor quality. To recover deep percolation losses from irrigation, pumping will need to be limited to the top ground water built up by such percolation. Such recovery would have to wait until a sufficient depth of ground water from project operations had been built up to permit such top pumping. This will result in the delivery to the lands served of their full water requirement in the early years of project operation.

This area would probably develop more advantageously in smaller units having self-contained lateral systems where each such unit may create local proof of ability to finance that will assist later units. This would mean a longer time of development. In such cases development will require moving in many new settlers able to finance extensive farm improvements and operate under conditions of high cost water. Costs for local distribution would have to be incurred in full at the start of development instead of independently by each owner when he is ready as under pump development. This area has no cotton history.

The Semitropic Ridge area is now about one-half developed. If served it should be expected to use project water only slowly. Its present costs of pumping are less than the proposed project rates. Ground water is lowering more slowly and present lifts are less than in other proposed service areas. Difficulties are being encountered with the formation of scale in the wells resulting from the chemical quality of the local ground water. The Shafter-Wasco Irrigation District to the east is now securing a supplemental supply from the Central Valley Project. This should raise the ground water on the uphill side of the Semitropic area and cause some increased ground water movement into this area. The better Semitropic lands are already in use and the remainder will probably come in slowly under any conditions.

The Semitropic area is on the east side of the valley trough. To date there has been no plan presented for getting water to it from the Feather River Project although it is shown as a service area in the State Engineer's Report. A cross-valley siphon in the Elk Hills area appears to be the most desirable location for such a delivery. The cost of such delivery would be large for the area to be served.

It is considered that the Semitropic area should not be included as a prospective market for Feather River Project water. This represents our conclusion that no revenue from sale of water to the Semitropic Ridge area should be relied upon in the financial plans of the project in its early years of operation. Eventually means for delivery of project water to this area may be found which will be financially feasible.

Should project water be made available to the Semitropic Ridge area, the estimated ultimate demand shown in Table IX of the Institute's report is considered to be as representative of the probable use as any estimate that can be made at the present time. This estimate is 127,000 acre-feet per year for 58,000 acres of presently irrigated land and 121,000 acre-feet per year for 55,000 acres not now irrigated. Probable use of project water is considered to be 50 percent in five years, 75 percent in 10 years, and full use in 15 years after service may begin.

To reach the Wheeler Ridge area the Feather River Aqueduct would have to extend past Buena Vista Lake and around the south end of the Valley. This would be a long extension to reach an estimated ultimate demand for 194,000 acre-feet per year. If a route to Southern California should be adopted which passes by this area such service could be rendered from its canal. If a lower elevation coast route may be selected, the feasibility and size of any extension to serve Wheeler Ridge should be further studied. If water is delivered here the rate of demand might be similar to that previously estimated for the Kings County area.

The preceding estimates of the demand for project water in the different proposed service areas in the San Joaquin Valley are assembled in the following table. The time periods shown are those beginning with the date of initial service to each respective area. The project would probably not be completed to begin service to all areas simultaneously. Particularly service to the Semitropic Ridge might be delayed for 10 years until such service might be worked out on a financially feasible basis. Unless a route passing Wheeler Ridge is finally adopted for delivery to Southern California, extension of a canal to Wheeler Ridge might also be deferred. If any project is built it is to be expected that it would be completed for initial service to Fresno and Kings County. Extension to Antelope Plain might follow quickly or might be deferred until construction of the extension to Southern California is undertaken. The approximate area totals are shown in the table for the different five-year time periods and represent demands by areas after initial deliveries to the respective areas. The total eventual irrigation demand when all of these areas may be fully served would be 2,291,000 acre-feet per year. This is the same total demand shown in

ESTIMATE OF DEMAND FOR PROJECT WATER

Year	Irrigation Use					Urban Use	Total for San Joaquin Valley
	Fresno County	Kings County	Antelope Plain	Semitropic Ridge	Wheeler Ridge		
1	300	75	0	0	0	30	405
5	757	138	0	0	50	51	996
10	990	207	112	60	97	74	1,540
15	1,000	247	281	124	145	78	1,875
20	1,010	277	421	186	194	78	2,166
30	1,010	277	562	248	194	78	2,369

(Quantities in thousands of acre-feet)

Table IX of the report of the Stanford Research Institute.

In the institute's report an ultimate urban and domestic demand of 78,000 acre-feet per year has been included in Table VIII. The results of the institute are based on usual standards and are considered acceptable. The above table, therefore, includes that estimate for use of water for municipal and industrial purposes.

Antelope Valley-Mohave Desert Area

The State Engineer's Feather River Report places the use of 600,000 acre-feet of the 1,800,000 acre-feet to be delivered to Southern California in the Antelope Valley-Mohave Desert area. The institute's report finds that the price which irrigation can afford to pay in this area is materially less than the cost at which project water can be delivered. It also finds that industrial and municipal use for many years to come can be met from local sources and would furnish only a limited market for project water.

Bechtel concurs with the assumptions on which these conclusions rest. No subsidies have been included in the project plans sufficient to enable water to be sold in this area at the price irrigation could afford to pay. Some water could be sold for industrial and municipal use at a price representing cost if the project canal passed through this area. This use would not justify delivery in this area unless the project canal is routed through Antelope Valley for other reasons, or if further investigation could demonstrate the economic feasibility of an appropriate size aqueduct from Quail Lake on Route 10 or service from Route 11.

On the above basis the expected demand for water for irrigation from the Feather River Project in the Antelope Valley-Mohave Desert area within a period of years required to meet project financial plans becomes very limited. This would release for other Southern California or San Joaquin use nearly one-third of the total supply planned by the State Report for delivery to Southern California.

The prospective municipal and industrial demand for water in the Antelope Valley is not sufficient to be a deciding factor in the selection of the route to be followed in delivering Feather River water to the South Coastal area. If a route through Antelope Valley should be followed some industrial sales may be made in the Antelope Valley. If such a route should be completed by 1976 there may be an industrial development in Antelope Valley which with the accompanying municipal use the institute estimates may represent a demand of 17,000 acre-feet at a price which would cover the cost of water delivered in this area. An irrigation demand of any significant amount would be dependent on a price for such use in the order of less than half the cost of delivery in this area. Unless a policy of such an extent of subsidization may be adopted no irrigation demand in this area should be included in project operation plans. For delivery after 1976 there may be a demand in excess of that estimated by the institute; to allow for the uncertainty regarding the rate of industrial expansion into this area, a demand at the proposed prices of 25,000 acre-feet in 1976 increasing to 50,000 acre-feet by 1991 has been assumed. In terms of the time after first delivery began this would represent 30,000 acre-feet after five years' operation, 40,000 acre-feet after 10 years, 50,000 acre-feet after 15 years and 60,000 acre-feet after 20 years.

South Coastal Area

The discussion in the institute report of the prospective demand for Feather River water in the South Coastal area covers the extent of the uncertainties involved. For irrigation use it is stated, page 48:

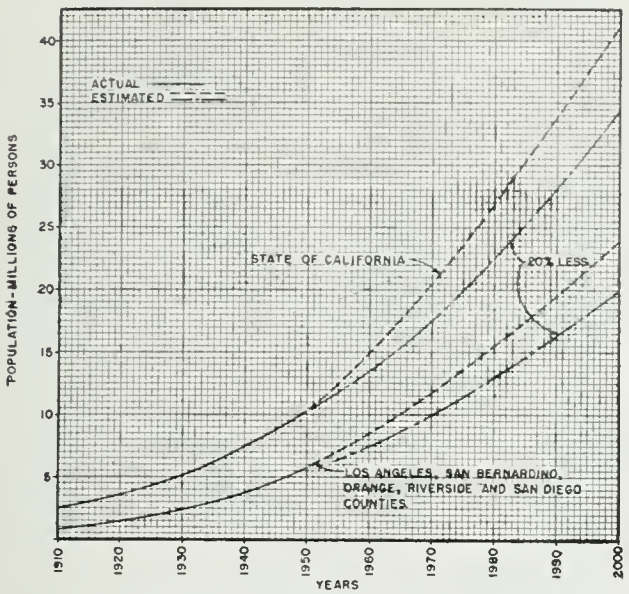
> "Because of the complexity of the analysis which would be required to project the demand for irrigation water in this area, it was not possible to undertake any study of this problem in the time available for this report."

Bechtel had directed the institute to confine its studies to urban demands because of that recognized situation. Present irrigation generally has water for its need although part of present use is obtained from overdraft on the ground water. Water for irrigation from the Feather River Project delivered in this area will be too expensive for use in large scale irrigation developments even if areas for such development were available. Future irrigation use, like much of the present use, will consist of suburban types where the cost of irrigation water may be high per acre-foot but will be low per family as a result of the small holdings and limited total per family use. Much of such suburban practice will be included, as it is now, within urban boundaries where the entire urban assessed value will be available for its financial support.

The institute's report discusses the factors affecting the urban water requirements and describes several of the variable factors involved. To meet the uncertainties of the future, separate estimates on different assumptions, particularly on population growth projections as represented on the following chart, were requested by Bechtel.

The institute's report recognizes that presently available sources will meet the increase in demands until 1970 to 1975. It accepts, for preliminary planning purposes, the schedule shown in the Feather River Project report. It recommends flexibility in plans and continued study. It is considered that this is a sound discussion of the situation involved. There are too many imponderables here to give value at this time to the selection of any specific date at which this

BASIC POPULATION PROJECTIONS USED IN ESTIMATING URBAN DEMAND FOR FEATHER RIVER PROJECT WATER IN SOUTHERN CALIFORNIA



NOTE DATA FOR 1910-1950 INCLUSIVE ARE FROM U.S. BUREAU OF CENSUS. FIGURES FOR 1955 ARE ESTIMATES BY CALIFORNIA TAXPAYERS ASSOCIATION. PROJECTIONS FOR 1960 AND LATER YEARS BY STANFORD RESEARCH INSTITUTE.

area will require Feather River Project water or use the full supply as may be allocated from the project.

The State Engineer's report starts with a water demand of 450,000 acre-feet in 1976 and increases to the full supply of 1,800,000 acre-feet in 1991. The increase is at a uniform rate of 90,000 acre-feet per year.

The State Engineer's report assigned one-third of the total delivery to the Antelope Valley-Mohave Desert area. The institute, however, finds urban demands in the South Coastal area which by 2000 will vary from 1,421,000 to 2,349,000 acre-feet per year (Table X) under different assumptions. To secure a demand in Southern California by 1991 of 1,800,000 acre-feet without delivery in the Antelope Valley, on the basis of the institute's estimates for urban demand, will require some demand for irrigation.

It is considered probably that the extension of the Feather River Project to the South Coastal area can be constructed at an incremental project cost which can be met from the sales of water after 1975 at prices which can be secured even though the demand and sales are less than those in Table 17, page 116 of the State Engineer's report. It is considered that there will be time to derive more definite conclusions relating to the demand before the costs of such an extension need be incurred.

For present planning purposes Bechtel recommends the use of a composite of the results shown in Table X of the institute report. This has the virtue of being a single set of figures but may not have any more merit than any of the different results in Table X. It is based generally on a continuation of sewage discharge to the ocean and some continuation of overdraft in the early years.

Experience to date on high unit costs of conversion of sea water to fresh water does not warrant currently placing any reliance on such sources at this stage of planning water supplies. Sewage reclamation represents a feasible source of supply for use in some areas. It is more liable to be used if the importation of outside water should be delayed and sewage reclamation becomes a matter of necessity. If the Feather River Project is constructed on a schedule similar to that in the State Engineer's report, sewage reclamation will probably be practiced on only a limited scale in the earlier years of Feather River Project operation.

While some use of imported water can be deferred by a continuation of the present ground water overdraft, eventually ground water exhaustion at feasible lifts will force use of project water. Consequently the estimates of the institute based on the elimination of the present overdraft are considered to be applicable to the future conditions.

It is Bechtel's conclusion that the recent population growth tendencies are accelerated by present conditions and reliance should not be placed on their continuance. For financial analyses of the Feather River Project the rate of demand in the institute report based on a 20 percent reduction in the recent population growth tendencies is considered to furnish a sounder basis for project planning.

The schedule recommended for present use is as follows:

Estimated demand in South Coastal Area for Feather River Project water for all uses.

Year	*Estimated demand*
1976	200,000 acre-feet
1980	600,000 acre-feet
1985	1,000,000 acre-feet
1990	1,300,000 acre-feet
1995	1,600,000 acre-feet
2000	1,800,000 acre-feet

It must be recognized that any estimate that may be made of the future water needs of the South Coastal area will fail to satisfy some local interests. This is illustrated by the recent San Diego County report of the San Diego County Water Authority and its review by the Hill, Longwell and Rankin Board of Consultants. In general terms the authority report sees very large growth occurring relatively quickly. The consultants express some cautions regarding the availability of water and the rate of increase in its demands. The authority report anticipates complete use of the remaining Colorado River supply in a few years. The consultants foresee a reduction in the Colorado River supply previously considered to be available but anticipate a slower increase in demand.

There has been much discussion in the South Coastal Area regarding the growth of demand in the Metropolitan Water District of Southern California. For

the first few years of its operation the district followed a conservative policy in annexations. Growth in demand for Colorado Aqueduct water in its original units was steady but not spectacular, due to ability to overdraw extensive ground water basins. More recently the district has encouraged annexation and has materially increased its area. Much of the area added also had ground water deficiencies and extensive areas previously undeveloped. The new areas have increased the total use by the district very materially.

Alameda-Santa Clara-San Benito Counties Service Area

The institute finds an ultimate demand of 219,600 acre-feet per year. This is comparable with the State Engineer's estimate of 240,000 acre-feet. There is an actual and urgent demand in parts of this area but there can be differences in conclusions regarding how much water may be needed. The extent to which San Francisco and the East Bay Municipal Utility District will commit themselves to permanent service of the parts of this area to which they are now supplying water is not definite.

There will be need of limited amounts for urban use in San Benito County. There is also a demand for irrigation use at a price which is less than those proposed for the Feather River supply. Over the last 25 years there have been a number of engineering studies made of storage on local streams, however, only one project has been built. San Benito County has local water resources for some local development but so far local interest in water at the costs of these projects has not been sufficient to result in their construction. The branch canal to Santa Clara County should not rely on any sales in San Benito County. If such a branch should be built, its extension to San Benito County can be decided on the then existing conditions.

It is recommended that the plans for service to Alameda and Santa Clara Counties should be included in the Feather River Project with the probable demand based on the results in Table XI of the institute's report.

The State Engineer's report, Table 17, uses delivery beginning in 1964 at 60,000 acre-feet and increasing uniformly 12,000 acre-feet a year to 1979 when the ultimate demand of 240,000 acre-feet per year would be reached. The institute report (Table XI) estimates a demand in 1960 at 36,000 acre-feet per year, increasing to the ultimate demand in 2000. There is little specific basis on which to make a selection between these two estimates, however, it appears reasonable to accept the State Engineer's approach on the demand in the early years of operation when present overdraft would be replaced and to extend the period for full development to the year 2000 as has been done in the institute report.

On this basis the estimated demand would be—

1964	50,000 acre-feet
1970	100,000 acre-feet
1975	125,000 acre-feet
1980	150,000 acre-feet
1985	175,000 acre-feet
1990	200,000 acre-feet
1995	220,000 acre-feet

The above definite schedule is presented mainly because some specific rate of demand is essential in computing costs and revenues for the project. It is considered to be consistent with present information but actual use may depart in either direction from this forecast based upon the limited studies permitted in the time for this review.

Feather River Service Area

The water demands of this area have been considered in our water supply studies. Its net use will decrease the Feather River Project water supply available for use in other project units. It appears unrealistic to anticipate any revenue from such use of water in the Feather River area in estimating the projects financing.

There will be benefit to this area by the improved water supply it will receive just as there has been benefit to the existing Sacramento River canals from the release of Shasta storage. Twenty years after the initiation of the C. V. P. no basis has been reached for collecting revenue from the Sacramento River canals. There will be no basis for preventing use of Oroville storage unless all Feather River rights below the reservoir are adjudicated prior to completion of reservoir construction, however, the propects of achieving an equitable solution should continue to be pursued by the State.

SUMMARY

The following table compares the results of the estimates developed by Bechtel with those of the State of the demand, and the rate at which it will develop for the proposed service areas in the San Joaquin Valley.

Years of project operation	*Thousands of acre-feet*	
	State Engineer	*Bechtel*
1	600	405
5	600	996
10	1,200	1,540
13	1,584	1,750
15	1,840	1,875
20	1,840	2,166
25	1,840	2,369

About one-half of the proposed total demand is for land in Fresno and Kings Counties which is now using water under conditions of major ground water overdraft and high lift. Conversion to the use of project water should be relatively rapid in this area. The next largest proposed service area is the Antelope Plain where there is relatively little present development

and the principal past interest has been in oil production. Use of water may be expected to occur slowly in this area. The practicability of serving the Semitropic Ridge area from the Feather River Project is questioned but it has been included as a delayed user. Similarly an extension to Wheeler Ridge is delayed until the fifth year upon the assumption that the feasibility of such an extension may have been shown by that time.

The State Engineer's report represents his allocation to this area as a possibility from the project supply and not as a determination of potential demand.

The conclusions in this table are based on the assumption that all areas proposed for service by the State Engineer will be available for such service and not previously supplied from some other source such as the proposed San Luis Unit Project of the U. S. Bureau of Reclamation; that firm contracts for sale of water are secured from properly organized and responsible local agencies in advance of construction; that such local agencies are also able to finance the cost of their local distribution systems without aid from the State; and that the present general conditions of price and demand for crops continue.

For the Southern California areas the estimates of the State Engineer and Bechtel's estimates are compared in the following table. The results of the State Engineer are based on one-third of this supply being used in the Antelope Valley-Mohave Desert Area. Our estimate finds irrigation unable to meet the project costs for delivery in this area and finds only a limited amount of municipal and industrial demand. The demand for general urban uses in the South Coastal Area over the time period shown is considered to be large enough to absorb the use planned by the State Engineer in the Antelope Valley-Mohave Desert Area. Both estimates are based on delaying delivery to Southern California until its Colorado River supply is fully used. This date is estimated to be 1976.

Years of project operation in Southern California	*Thousands of acre-feet*	
	State Engineer	*Bechtel*
1	450	200
5	810	600
10	1,260	1,000
15	1,710	1,300
20	1,800	1,600
25	1,800	1,800

The estimates for the South Coastal Area are based on the assumption that a firm commitment will have been made by an agency or agencies responsible for receiving, distributing and paying for the water to be delivered to this area in advance of the project extension to this area.

The estimates of the demand in the Alameda, Santa Clara, and San Benito Counties Area are in fairly close agreement and furnish a basis for analyzing the cost and returns from this unit of the proposed project.

Bechtel is in general agreement with the State's estimates regarding the amount of demand that may develop from lands in the Feather River Service Area which will be served by diversion from Feather River after the construction of Oroville Reservoir. Revenue from the sale of project water to such areas should not be anticipated unless firm contracts for such use can be secured.

The total demands that may develop for the project as a whole as concluded by Bechtel are summarized in the following table. These results are subject to the limitations that have been expressed in this summary and amplified in the main portion of these comments.

	Thousands of acre-feet					
Year	*San Joaquin Valley*	*Antelope Valley-Mohave Desert*	*South Coastal Area*	*Alameda, Santa Clara, San Benito Counties*	*Feather River Service Area*	*Total*
1960	539	--	--	--	No	539
1965	1,214	--	--	58	revenue	1,272
1970	1,674	--	--	100	pro-	1,774
1975	1,991	25	--	125	ducing	2,141
1980	2,206	30	600	150	demand	2,986
1985	2,308	40	1,000	175		3,523
1990	2,369	50	1,300	200		3,919
1995	2,369	60	1,600	220		4,249

Actual dates have been used in this table as a convenient method for indicating the delay in delivery to some project units. The table follows the report of the State Engineer in placing the initial delivery in 1960 although this date is now probably not realizable. The amounts shown include some deliveries for which the feasibility of service to local areas has been questioned, as were discussed previously.

The results presented herein represent conclusions regarding the maximum rate of use of project water on which financial plans for the project should rely. The use of any specific results for water sales in project financial forecasts should not result in overlooking the degree of uncertainty that is involved in any attempt to forecast project water demands over the next 40 years.

CHAPTER VI

FINANCIAL FEASIBILITY

INTRODUCTION

The magnitude of the Feather River Project as reported upon by the State Engineer, and estimated by the State Report to cost approximately one billion five hundred million dollars ($1,500,000,000) for the High Line route, represents an imposing financial obligation. Bechtel, by the terms of the contract, which are in accordance with the language of Senate Concurrent Resolution No. 42, was requested also to review the financial feasibility of the proposed project.

The report of the State Engineer concluded that the project is feasible under state financing through the issuance and sale of general obligation bonds of the State, secured by water and power revenue and contributions from the General Fund of the State. Bechtel retained the financial firm of Blyth and Company, in association with the Heller Bruce Company and Stone and Youngberg Company, to make certain studies and submit their conclusions and recommendations relative to the financial aspects of the project.

These studies were directed towards evaluating the financial feasibility of the financial program as proposed by the State Engineer's Report, or proposing a better financial program. Certain basic data relative to estimated construction costs and construction time schedules, and estimated project revenues and annual costs exclusive of bond service as developed by Bechtel's engineering and economic review were furnished the financial consultants. Estimates of population growth in the State of California as prepared by our consultants, Stanford Research Institute, were also furnished.

The principal purposes of this financial study, its scope and the comprehensive considerations leading to the conclusions of these financial consultants are well covered in their joint report to Bechtel. This report is included herein as Appendix B.

It should be particularly noted in Bechtel's Routes Nos. 8-A and 10-A, that, while the contributions by the General Fund have been extended over a longer period of years, they are considerably reduced from the peak amounts required in the analysis using the State's financing program in the period from the eleventh to the forty-first year. If the State should so desire, it is quite possible that the price of water could be redneed several dollars per acre-foot if it wishes to maintain the schedule of State General Fund contributions outlined in the State Report for those years.

The substance of the conclusions of the financial consultants, in which Bechtel concurs, are summarized hereinafter.

CONCLUSIONS

Estimated capital costs of the proposed Feather River Project are such as to require the issuance of bonds. Prospective project revenues during the initial stages preclude consideration of revenue bonds as a means of financing. The issuance of State of California general obligation bonds, to which net revenues of the project are specifically pledged, is recommended as being the most economical and practical means of financing. Any project legislation should be enacted with great care and consideration so that necessary flexibility in financing procedure will be provided.

Funds for the payment of interest and principal of bonds would be derived to the extent possible from net project revenues and any balance from the State's General Fund.

We have developed a financing program that provides for amortization coinciding more closely with project revenues, normal growth factors, and well within the expected life of the project facilities with amortization to be completed in 70 years. The state program provided a heavier annual bond service requirement in the initial stages of the project than we believe necessary.

The use of term bonds having fixed maturity dates of not to exceed fifty years from date of issuance, with suitable provisions for prior redemption and refunding, is recommended as a means of providing satisfactory flexibility in the financing program.

Judging from past records and present prospects, it is estimated that the bonds should be salable at an average interest cost of 2.7 percent during the approximate 30-year construction period.

Maximum annual bond sales projected for Routes Nos. 1 (State's High Line) and 10-A (Bechtel's Modified High Line) do not exceed greatly the amounts of many single bond issues sold elsewhere in recent years and consequently should not present difficulties insofar as marketability is concerned. Those projected for Route No. 8-A (Bechtel's Modified Coastal Line) in the seventeenth to nineteenth years, being considerably greater in magnitude, may do so.

The financial requirements of the project appear to be moderate, in relation to probable population, income and wealth of the State.

Therefore, it is our considered judgment that, subject to the conditions outlined herein, it is feasible to finance the Feather River Project with general obligation bonds of the State.

DISCUSSION

As previously discussed in this report, it is not possible to make exact comparisons of the seven routes, as reported upon by the State Engineer, either among themselves or with any of the four modified routes studied by Bechtel, since the routes do not terminate at the same point or deliver the same amounts of water to the several areas and, in some instances, they do not even serve the same areas.

In an attempt to achieve as common a basis as feasible, the four Bechtel Route Modifications Nos. 8, 9, 10 and 11, were routed to a common terminal point in the San Fernando Valley. These routes were then compared among themselves, as well as with the State's seven routes, on a comparative cost of water basis developed for such purposes only. These studies are covered in Chapter III of this report in the section title, "Comparison of Alternate Routes to Southern California."

As also discussed in the same section of Chapter III, Routes Nos. 8 and 10 were then selected, and recommended modifications reflecting changes in scope and sequence of construction, project operation, schedules of water deliveries, and applicable costs and revenues as developed by Bechtel studies, were incorporated.

These two routes, now titled Routes Nos. 8-A and 10-A, were then analyzed from a financing point of view as follows:

The State's Financial Analyses were predicated upon an assumption that the Big Bend Power Plant would be purchased in the first year of construction of Oroville Dam, and that it would be operated by the project agency to yield an interim power revenue for the following three and one-half years. The net revenue from that operation was assumed by the State Engineer's analyses to be utilized for payment of construction costs in the year following its receipt. Bechtel, in its financial analyses of Routes Nos. 8-A and 10-A, did not take such credit, as it is considered somewhat doubtful that such a utility operating property could be taken until the date that its further operation would be precluded by the filling of the Oroville Reservoir. Acquisition of Big Bend Power Plant was delayed accordingly in our cost schedules.

Also, solely for comparison purposes, the indicated charges for water used in the financial analyses for Routes Nos. 8-A and 10-A, Schedules 8-A and 10-A, Appendix B, are the same as those used for Alameda-Santa Clara and San Benito Counties, for the Fresno-Kings area, and northern Kern County and for southern Kern County in the financial analysis of the proposed High Line Route in the State's Report.

Bechtel's proposed modifications in design and operation of the project are incorporated in Routes Nos. 8-A and 10-A, and are estimated to result in a saving in pumping plant power requirements over the 70-year amortization period of approximately $134,000,000. These savings are reflected in the financial analyses of each of Routes Nos. 8-A and 10-A. Bechtel's financial analysis of the State's High Line Route No. 1 was made of the project as proposed by the State's Report and without incorporating similar proposed modifications in design and operation. On the assumption that these modifications in design and operation could also be incorporated in the State's High Line Route No. 1, a similar saving of the $134,000,000 could be achieved and would reduce the General Fund contribution of approximately $366,000,000, shown in Schedule 1 of Appendix B, to approximately $232,000,000.

Accordingly, for comparison purposes of cost of water to Southern California by Routes 8-A and 10-A, such costs were computed for each route so that the total outstanding General Fund contribution would be approximately equivalent to $232,000,000 at the end of the same 70-year bond amortization period.

Routes Nos. 8-A and 10-A are on an equivalent basis and show relative cost for water delivered by their respective routes to Southern California at the Granada Hills Reservoir on an equivalent financial basis. The financial analysis of Route No. 1 cannot be compared directly with those for Routes No. 8-A and 10-A, since total water deliveries and distribution to areas are not equivalent; however, the results are considered sufficiently representative for all three plans, for drawing proper conclusions.

Based upon the foregoing, the following charges for water were used in these financial analyses:

	Water charges, dollars per acre-foot Route No.		
Service area	*1*	*8-A*	*10-A*
Fresno-Kings, Northern Kern Counties	$8.00	$8.00	$8.00
Southern Kern County	9.00	9.00	9.00
Alameda, Santa Clara, San Benito Counties	22.50	22.50	22.50
Southern California	45.00	42.90	33.90

The comparison between Routes Nos. 8-A and 10-A shows that Route 10-A is more economical from the standpoint of the cost for water.

The construction cost estimates for Route No. 10-A include an allowance for providing regulating features between Pumping Plants Nos. III and VI, not contained in the estimates for Route No. 1, the latter being limited to only those structures proposed by the State. Providing an equivalent allowance for such features for Route No. 1 would further increase

the price of water to Southern California, by approximately $1.50 per acre-foot for that route.

Route No. 10-A includes power revenues from the Castaic Power Development. It is estimated that water deliveries to Southern California would be primarily urban and approach uniformity throughout the year, and that the Granada Hills Reservoir would permit small variations in drawoff quantities. A major consideration associated with the Feather River Project is that water would be transported for great distances and considerable pumping lifts are required. In order for the project to be able to deliver water at the lowest cost, it is very desirable that maximum use be made of the project's Southern California hydroelectric generation facilities and that they be integrated into existing power systems, as a base load source of supply for maximum revenue.

The costs of water developed for Route No. 10-A were based upon such on-peak power generation and sales. To place the delivered cost of water by this route in the most unfavorable light, the power revenues from the Castaic Power Development were also computed upon the basis of sale equivalent to off-peak prices. Such reduced power revenues were found to require an increase in cost of delivered water to Southern California of about $5 per acre-foot, or a total cost of $38.90 which is still favorable, compared to costs of $42.90 for Route No. 8-A and $45 for State High Line Route 1.

When the aqueduct is finally constructed to service Southern California, arrangements will be made for the sale of this power. If, in the initial years of the project, varying weather conditions require varying water deliveries and thus varying power generation, the power generated can be used to reduce off-peak pump power purchases.

Bechtel has not made a detailed study of final use of the power, but with the greatly increased power requirements of California, 20 to 30 years from now, we feel that this power, even in the initial phases of the project, will have a value greater than that of off-peak power.

It is emphasized here that these costs of delivered water are representative costs under the particular financing program developed in the financial studies. Respective costs of water could be increased or decreased with consequent decrease or increase respectively of contributions by the State's General Fund. Accordingly, as it is considered to be a matter of public policy for decision as to the project support to be derived from general funds, these comparative respective costs of delivered water are necessarily not presented as recommended prices.

APPENDIX A

REPORT
STANFORD RESEARCH INSTITUTE

DEMAND FOR WATER IN SERVICE AREAS OF THE FEATHER RIVER PROJECT

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November, 1955

DEMAND FOR WATER IN SERVICE AREAS OF THE FEATHER RIVER PROJECT

by

NEIL T. HOUSTON
WILLIAM BREDO

SRI Project 1512

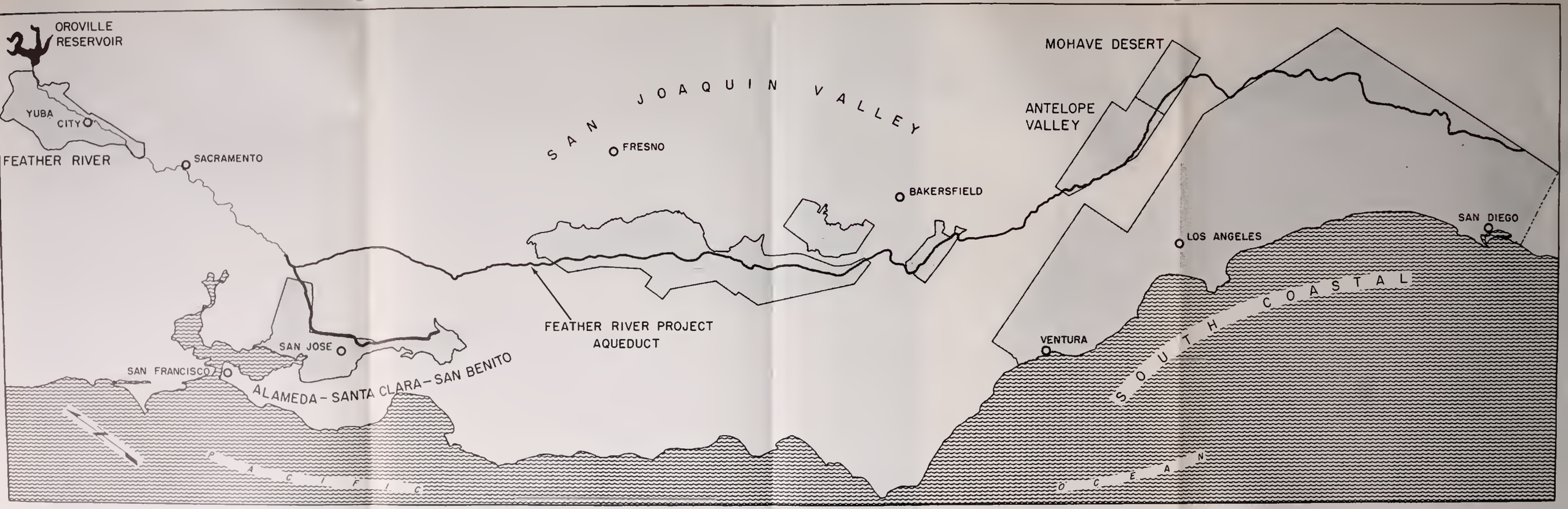
Prepared for

BECHTEL CORPORATION
San Francisco, California

Approved:

WILLIAM J. PLATT, Assistant Director
Economics Research Division

WELDON B. GIBSON, Director
Economics Research Division



Source: Feather River Project Report — Plate 2

D-1512-1

FIG. 1

FEATHER RIVER PROJECT
AREAS WHICH COULD BE FURNISHED SUPPLEMENTAL WATER

SECTION I

INTRODUCTION

The Joint Committee on Water Problems of the Legislature of the State of California selected Bechtel Corporation to make an independent review of the report *Program for Financing and Constructing the Feather River Project as the Initial Unit of the California Water Plan,* submitted by the State Engineer in February, 1955. In connection with this review, Bechtel Corporation asked Stanford Research Institute to study the demand for water which could be expected to develop in each of the areas which the Feather River Project is intended to serve. This report presents the results of that study.

The Feather River Project report shows areas in California which could be served with water from the proposed project. It also indicates time schedules on which certain quantities of water could be delivered to these areas, and it shows, in its financial analyses, project income based on certain average revenues for the water delivered. The physical features of the project are designed, and their construction planned, for the purpose of meeting these water delivery schedules. The financial features of the project are planned to utilize income from the scheduled sales of water. It is therefore basic to the entire program that these water delivery schedules and revenues reasonably represent those which could be expected actually to prevail if the project is built.

In the present study, the work of the California Division of Water Resources in establishing the water delivery and project revenue schedules shown in the Feather River Project report was first reviewed. To determine the methods used in deriving the schedules of water delivery and the associated revenues, these matters were discussed in detail with members of the Division of Water Resources assigned to this work on the Feather River Project.

When it was found that these schedules are not based on economic studies of the service areas, Bechtel Corporation asked that such studies be made to the extent possible in the limited time available. Each of the service areas was then independently studied to determine whether the scheduled quantities of water could indeed be sold in return for the average revenues indicated in the Feather River Project report.

This work was done in the Economics Research Division in September and October, 1955, under the direction of Dr. Neil T. Houston, project leader, and Dr. William Bredo, senior agricultural economist. Parts of the research were conducted by A. Gerlof Homan, W. Lawrence Prehn, Jr., and J. K. Kipp. Other staff members contributing to the work include Carol Van Alstyne, John Huneke, and Howard Nielsen.

Much use was made of data from published reports of the Division of Water Resources and the United States Bureau of Reclamation covering the service areas or adjacent similar areas. These were supplemented by information obtained in personal interviews in these agencies. In addition, reports and unpublished data supplied by water agencies in the various service areas were valuable sources of information. Field work was done in each of the service areas. Many personal interviews with representatives of water agencies, agricultural officials, ranchers, power companies, and others with knowledge of local water conditions were obtained, and they provided valuable data.

The research staff wishes to acknowledge the excellent cooperation and assistance received from members of the Division of Water Resources. Much appreciation is also due personnel of the United States Bureau of Reclamation. In the various service areas, officials of water agencies and other persons too numerous to mention individually contributed most generously in time and information.

SECTION II

SUMMARY AND CONCLUSIONS

Review of Feather River Project Report

Discussion of the Feather River Project report with members of the Division of Water Resources brought to light information helpful to a better understanding of those aspects of the report dealing with water deliveries and water revenues.

It is important to recognize that it was not within the scope of the Feather River Project report to make a firm allocation of water among the various areas which could be served by the project and to establish the prices at which water would be sold in the areas served. Decisions on these basic questions have not yet been made by appropriate authority. In the absence of such decisions, it was necessary for the writers of the report to make assumptions on these and related matters in order to provide a basis for project design.

The service areas outlined in the Feather River Project report are general areas thought to be within reasonable distribution distance of the aqueduct. This does not necessarily mean that water would be made available throughout those areas, nor that water sales would necessarily be restricted to those areas. For purposes of the report, certain quantities of water are shown as delivered to the possible service areas. These quantities were determined after consideration of data developed by the Division of Water Resources in the preparation of State Water Resources Board Bulletin No. 2, *Water Utilization and Requirements of California.*

With respect to future water requirements, this bulletin is concerned with the ultimate needs of the State after it is fully developed, rather than with the rate at which water needs may grow during the development period. The total water to be made available by the Feather River Project is not sufficient to meet all the probable ultimate requirements of the possible service areas as estimated for Bulletin No. 2. Available project water was assigned to the possible service areas to satisfy part of the ultimate needs of each area, and time schedules of deliveries were established. No studies were made on the rate of growth of water demand in the possible service areas.

The financial analyses in the Feather River Project report show average revenues per acre-foot of water delivered in the possible service areas. These average revenue figures are not intended to be recommended or predicted water prices. Rather, they represent the average revenue which would be required in each area for that area to pay its share of project costs as indicated in the financial analyses. These revenues are not necessarily related to the ability of water users to pay; and if the project is built, the water might actually be sold at a variety of prices within these large service areas.

If the project were built as proposed in the Feather River Project report, and if the actual water deliveries developed differently from those shown in the report, or if the average water sales revenues realized were different from those in the report, the financial aspects of the project would obviously also be different. Obligations of the General Fund would be larger or smaller, depending on the water deliveries and water prices. It is imperative in project planning, therefore, to have the best possible estimates of probable water deliveries and probable water prices. Unfortunately, the Feather River Project report does not reflect an analysis of these subjects. This creates uncertainties as to the desirable size of project features, the time schedule of construction, and the financial outcome.

Although it is never possible to eliminate uncertainty in planning for the future, the degree of uncertainty can be reduced through study of those factors which will affect project outcome and through securing certain commitments before the final decision to proceed with the project.

Much of the uncertainty which now surrounds the Feather River Project could be removed by reaching a firm decision on the quantities of water to be allocated to each of the major service areas. Uncertainty would be further reduced by establishing a water price policy for the project and by advance agreements with major potential customers. Decisions such as these are matters of public policy, since they have a great effect on the distribution of project benefits and project costs among the people of the State. They cannot be decided entirely on the basis of engineering or economic research. Research can, however, indicate the range of possibilities which can be used as a basis for making these decisions.

Demand for Water in Major Service Areas

The importance of the water delivery schedules and water prices to the design, construction, and financing of the project has already been mentioned. When it was found that these aspects of the Feather River Project report do not rest on economic analysis of the service areas, Bechtel Corporation requested that

these subjects be studied to the extent possible within the limited time available.

In this study it was necessary to concentrate on those points significant to the project which could be meaningfully analyzed in a short time. The work summarized here is, therefore, necessarily selective. It does not fully cover the broad subject of economic feasibility, nor does it fully cover even the narrower topic of water demand.

The study of demand for any product includes consideration not only of the quantities of the product which can be sold but also consideration of the prices at which various quantities can be sold. Thus, it is not possible to consider the delivery of a quantity of water in an area without reference to the price at which that quantity will be bought. Prices for Feather River Project water have not been determined, and it was not possible in the short time available for this study to work out the probable results of a range of possible prices. The average revenue figures indicated in the Feather River Project report as necessary to cover costs in each service area were used as assumed water prices in this report, and the effects of variations from these levels are shown when they could be readily ascertained.

The possible service areas are shown in Figure 1. An analysis of the water demands of each service area follows.

San Joaquin Valley Service Area. The first large area which could be supplied with water from the project consists of lands on the west side of the San Joaquin Valley in Fresno, Kings, and Kern Counties. Almost all of the water used in this large area is for irrigation. Urban water requirements are relatively small and are expected to remain so in the forseeable future.

It is estimated that approximately 500,000 acres are now being irrigated in this area. Large acreages are in all units except Antelope Plain, with the largest concentration being in the West Side unit. The need for supplemental water in the presently irrigated areas is acute. Ground water levels are falling rapidly, and pumping depths exceed 400 feet in many cases.

Average water revenues shown in the Feather River Project for this area range from $7 to $9 per acre-foot. It was not possible to study local distribution costs in this area in detail, but estimates based on experience in nearby areas indicate that with these prices at the aqueduct, Feather River Project water could be delivered to these lands at costs which are not much higher than present costs of pumping. It is estimated that presently irrigated lands would provide an annual market for more than 1,000,000 acre-feet of water in the $7 to $9 price range within eight years after deliveries are begun.

In addition to the presently irrigated lands, in this large service area there are more than 500,000 acres of land which probably would be irrigated if water becomes available. This land is similar enough to that now being irrigated to indicate that it, too, would be economically irrigable with water priced at $7 to $9.

It is estimated that this potentially irrigable land would provide a market for about 1,200,000 acre-feet of project water within 13 years after water becomes available.

The Feather River Project report envisions the initial delivery of water in the San Joaquin Valley area in 1959, with the annual delivery reaching 1,840,000 acre-feet 14 years later. With the Coastal Line or the Long Tunnel Line, deliveries to this area are shown reaching 2,416,000 acre-feet by 1991.

The estimates made in the present study indicate a market for 2,290,000 acre-feet of irrigation water by 1972 (and less than 80,000 acre-feet for other uses), with a potentially more rapid development than that shown in the Feather River Project report. There are some possibilities for deliveries outside the service area, as well as the possibility that land of lower grades than that considered irrigable here would be developed. It therefore appears that the Feather River Project report figures for selling project water in the San Joaquin Valley service area in the $7 to $9 per acre-foot price range are conservative.

Southern California Service Area. The Feather River Project report indicates two possible service areas in Southern California—the Antelope Valley-Mohave Desert region and the South Coastal Area. (See Figure 1.) The first delivery of water to these areas is scheduled for 1976, beginning with 450,000 acre-feet in that year and increasing to 1,800,000 acre-feet by 1991. Of this total delivery in 1991, some 600,000 acre-feet could be supplied to the Antelope Valley-Mohave Desert region, with the remainder going to the South Coastal Area.

Antelope Valley-Mohave Desert. This region lies at an elevation of about 2,500 feet and is subject to extreme temperature variations. The area—whose chief crop is alfalfa—is not climatically adapted to the high value crops or multiple cropping pattern which characterize many other parts of Southern California. Some 42,000 acres are presently irrigated with water pumped from wells at costs ranging from $7.50 to $10.50 per acre-foot.

A vast additional area could be irrigated if cheap water were available. However, the $25 to $45 per acre-foot, which the Feather River Project report indicates as the average revenue required in Southern California for that area to pay its share of project costs, is clearly more than irrigation users in the Antelope Valley-Mohave Desert region could pay. The desert region cannot be considered a potential market

for irrigation water which costs the farmer appreciably more than he is now paying. Thus, when distribution costs from the Feather River Project aqueduct are also considered, it can be seen that purchasers of irrigation water could pay only a small part of the cost of supplying project water to this area.

There are several small urban communities in the Antelope Valley-Mohave Desert region. These communities have enjoyed rapid growth in recent years; but even allowing for continued rapid expansion here, the urban market could not be expected to take a significant part of the water scheduled for delivery in Southern California.

South Coastal Area. Agricultural development in this area is complex because it is influenced by extreme variations in soils, topography, and climate. For this reason, it was not possible to consider the economics of new irrigation in the South Coastal Area. However, new irrigation developments could possibly have an important influence on the time at which Feather River Project water is needed in this area and on the rate at which demand builds up. A thorough study of this problem is warranted in planning for the project.

The principal demand for project water in the South Coastal Area will come as a result of further growth of the large urban communities in the vicinity of Los Angeles and San Diego. These communities can readily pay the cost of Feather River Project water, and if their growth continues in the patterns characteristic of recent years, they could by the end of the century use the entire 1,800,000 acre-feet indicated for delivery in Southern California.

Several important factors create uncertainty with respect to the date on which there will be a significant demand for Feather River Project water in the South Coastal Area and with respect to the rate at which demand will subsequently develop.

The principal urban communities are in the Metropolitan Water District of Southern California, which has rights to large quantities of water from the Colorado River. This water is only partially utilized at present, and the unused supply available from this source will meet the needs of the Metropolitan Water District for some time to come. Further, a large part of the area can secure a major share of its needs by pumping from wells at low cost. As a result, the ground water supplies are being used at a much faster rate than they are being replenished. How long this situation can continue is uncertain. Obviously it cannot continue indefinitely; and when the ground water is used only at its safe sustained yield, the demand for imported water will be correspondingly increased.

In addition to these complicating factors on the supply side, there are the uncertainties surrounding future population growth and the future water consumption rates for domestic, industrial, and municipal purposes. The time and extent to which areas not now on ocean outfall sewers will discharge their waste water to the ocean in the future are also indefinite and this affects the replenishment of underground water supplies.

The growth of urban demand for Feather River Project water was studied under a series of assumptions which allow for various contingencies with respect to these uncertain factors. If recent trends in population growth and water use continue, and if all the principal urban areas are sewered to the ocean, it is estimated that over 200,000 acre-feet of Feather River Project water would be required in 1970 in order to eliminate the overdraft on ground water. This would increase to about 500,000 acre-feet in 1975. If the population growth were to be 20 percent less than recent trends would indicate, these demands would be postponed about five years. If the communities in the Riverside-San Bernardino area are not sewered to the ocean, the effect would be a further postponement of these demands about two years and a somewhat slower rate of increase in subsequent years. To the degree that ground water overdraft can continue in the future, all of these demands would be correspondingly reduced.

The Feather River Project report shows an initial delivery of water in Southern California of 450,000 acre-feet in 1976. The foregoing estimates of demand, which do not include any allowance for new irrigation, indicate that a market for approximately this quantity should exist in the South Coastal Area alone. The report shows deliveries reaching a maximum of 1,800,000 acre-feet in 1991, which includes about 600,000 acre-feet for the Antelope Valley-Mohave Desert region. Population growth in the distant future as the South Coastal Area becomes more nearly filled with people is difficult to predict, but the growth in urban water requirements alone will probably provide a market for the entire 1,800,000 acre-feet by the year 2000. The delivery schedule proposed for Southern California therefore appears reasonable.

The foregoing estimates were made on the assumpthat the full entitlement to Colorado River water claimed by the Metropolitan Water District will be available. If there were any developments with respect to that stream which reduced the water available to the district, the time when Feather River Project water is needed would be advanced and the demand on the project increased.

Alameda-Santa Clara-San Benito Counties Service Area. The northern part of this service area contains rapidly expanding urban communities which will have a growing need for project water. It is estimated that increasing water requirements resulting from urban growth would create a demand for project water of about 45,000 acre-feet by 1964. The Feather

River Project report indicates a delivery of 60,000 acre-feet to the area in that year.

Since the major part of the urban growth in the early years of the project will occur on land which is now irrigated, the increase in water requirements attributable to urban expansion will be rather gradual. The report shows deliveries reaching the total of 240,000 acre-feet allocated to this area by 1979. It is estimated that demand for project water resulting from urban expansion alone would total about 85,000 acre-feet in that year.

The foregoing estimates are based on the assumption that ground water resources will be used only to the extent of their annual safe sustained yield. If ground water overdrafts continue into the project period, the demand for project water would be reduced accordingly. The recent Alameda County investigation by the Division of Water Resources indicates the possibility of conserving local surface runoff through the construction of Sanatorium Dam, which would have an average annual yield of 13,200 acre-feet. There is presently no organized water conservation agency in the area near this possible dam site. However, if the dam were built, it would reduce the foregoing estimates of demand for project water accordingly.

The Feather River Project report shows that average water revenues from $17.50 to $22.50 per acre-foot, depending on the works constructed, would be required in this area to cover project costs allocable to the area. If water prices were fixed in this range, it is probable that some new irrigation development would occur. On the other hand, water at these prices appears too expensive for irrigation use on some of the farm lands in the area.

Because of the diversity of conditions in these counties, it was not possible in the present study to evaluate the potential irrigation demand for project water in sufficient detail to estimate the quantities which might be used for this purpose. Any irrigation demand would, of course, be in addition to that estimated above.

To determine whether the relatively slow development of urban demand would have important implications for project design or project financing, it would be necessary to study the irrigation potential in more detail. Even though it were found that irrigation demand would not make up the entire difference between the quantities estimated for urban use and the deliveries shown in the Feather River Project report, the urban communities could utilize the remainder of the water allocated to this area before the end of the century.

Feather River Service Area. Along the Feather River between Oroville and its junction with the Sacramento River, there is a large area of irrigated and potentially irrigable land. Numerous water users in this area have diversion rights in the Feather River. In 1952, about 730,000 acre-feet were diverted from the river in this area, of which about 400,000 acre-feet were consumptively used. Diverted water which is not consumptively used returns to the drainage system and does not reduce the amount of water available in the Sacramento-San Joaquin Delta for purposes of the project.

Control of the river by Oroville Dam would make the flow through this area more regular and would enable the diverters to utilize more water than is possible with the unregulated stream. This in turn will reduce the amount of water from the river which reaches the Sacramento-San Joaquin Delta for possible pumping through the project aqueduct.

Project operation, as described in the Feather River Project report, is based on an allowance for increasing the gross diversions in this area to 970,000 acre-feet, with net consumptive use increasing to 721,000 acre-feet.

The data and reasoning leading to the establishment of this allowance were reviewed. The question of water rights in this area is quite complicated, and it is not possible to foresee all the arrangements which might affect future diversions. However, it is believed that the situation was well analyzed by the Division of Water Resources; and in view of the total acreage which appears to have access to diverted water, the foregoing allowance should be adequate for the ultimate development of the area.

It is clear that diverters in the Feather River Service Area would derive benefit from the project. However, no revenue to the project from water service in this area is included in the financial analyses in the Feather River Project report. Despite the administrative difficulties involved in determining the extent to which the various diverters are benefited and in securing payment for these benefits, it may be possible to make some satisfactory arrangements. The Division of Water Resources is investigating this situation further.

SECTION III

REVIEW OF FEATHER RIVER PROJECT REPORT

Because the Feather River Project report does not explain the way in which the service areas were determined nor the ways by which the water delivery and revenue schedules were derived, the first step in a review of this work was to discuss methods and supporting data with members of the project staff in the Division of Water Resources.

This section contains a description of the information developed in these discussions, together with comments on the adequacy of the data and the adequacy of the analysis which led to the water delivery and revenue schedules.

It was found that the service areas shown in the Feather River Project report, and reproduced in Figure 1, represent large general areas along the aqueduct route in which a present or future need for imported water is known to exist. For the purposes of the report, the boundaries of the indicated service areas were established in a rather informal manner to include lands within a reasonable distribution distance of the aqueduct. With the exception of certain regulation and conveyance facilities for the Antelope Valley-Mohave Desert Area, no specific study was made of the cost of distribution works which would be required to deliver water from the aqueduct to points of use. The indicated service areas do not necessarily include all the lands along the aqueduct route having a need for water. Further, water service would not necessarily be made available throughout the indicated areas, nor would it necessarily be restricted to these areas.

In establishing the quantities of water delivered to each service area, data used in preparing the report were those developed by the Division of Water Resources for State Water Resources Board Bulletin No. 2, *Water Utilization and Requirements of California*. These data concern the needs of the areas under "ultimate" conditions of development.

The water which was considered to be available from the Feather River Project was insufficient to meet the ultimate needs of the service areas as estimated for Bulletin No. 2. For the purposes of the report, the available Feather River Project water was divided among the service areas to make some contribution to the ultimate requirements of each area. This does not represent an official allocation of water, which would be beyond the scope of the Feather River Project report. Rather, it represents the necessity to make some working assumption as a basis for project design. (See Table I for delivery schedules shown in the report.)

The date for the initial delivery of water in each area was determined in consideration of the needs of the area and the need to spread construction of project works over time. A rate at which additional quantities of water would be used after the initial delivery was assumed for each service area. No specific economic analysis of the service areas was made to determine the rate at which water demand might be expected to develop.

The financial analyses contained in the Feather River Project report are based on the water delivery schedules just described and on certain average water revenues per acre-foot delivered. (See Table II.) These average revenue figures do not represent recommended or proposed prices for project water, nor do they represent predicted prices or estimates of the ability of water users to pay. Rather, these figures represent the average revenue per acre-foot which would be required on the scheduled deliveries in each service area in order for each area to pay its share of the project costs under the financial plans shown.

Each area's share of the costs was calculated by assigning to that area all project costs incurred for the sole benefit of that area, plus a pro-rata share of costs incurred for the benefit of more than one area. Costs were prorated on the basis of acre-feet of scheduled water deliveries. All power revenues are credited against the cost of general project features and not against cost assigned to particular areas. The annual cost of power for pumping to a given lift for a service area was charged to that area.

For use in an economic analysis of the Feather River Project, the data and procedures just described have two serious deficiencies. First, the basic data on water needs in the service areas relate to "ultimate" requirements rather than to the actual rate at which the need may be expected to develop in the years of immediate concern to the Feather River Project. Second, the "revenue" figures are really cost allocations rather than estimates of the actual amounts which could be obtained from the sale of water.

Citation of these deficiencies is not intended as a criticism of the Feather River Project report. It was not within the scope of the report to establish a water price policy for the project. The ability of potential water users to pay and the problem of establishing a workable price structure for the water were not analyzed. Problems of local distribution of water in the service areas, which will have an important bearing on the cost and availability of water to consumers, have also not been covered in the project planning.

Some further explanation of the water requirements data in State Water Resources Board Bulletin No. 2 [1] will emphasize the lack of economic analysis to support the water delivery schedules shown for the Feather River Project. As previously mentioned, this bulletin deals with water requirements throughout the State under conditions of "ultimate" development. This situation is defined as "conditions after an unspecified but long period of years in the future when land use and water supply development will be at a maximum and essentially stabilized." [2] No estimate of the rate of development toward these ultimate conditions is made, and thus no data are provided on water requirements at intervals during the years ahead.

TABLE I

FEATHER RIVER PROJECT

SCHEDULE OF WATER DELIVERIES [1]

(Thousands of acre-feet)

Year	Fresno and Kings Counties	Kern County	Alameda, Santa Clara and San Benito Counties	Southern California	Total
1959	450	150			600
1960	450	150			600
1961	450	150			600
1962	450	150			600
1963	450	150			600
1964	520	300	60		880
1965	590	325	72		987
1966	660	350	84		1,094
1967	730	375	96		1,201
1968	800	400	108		1,308
1969	840	488	120		1,448
1970	880	576	132		1,588
1971	920	664	144		1,728
1972	960	752	156		1,868
1973	1,000	840	168		2,008
1974	1,000	840	180		2,020
1975	1,000	840	192		2,032
1976	1,000	840	204	450	2,494
1977	1,000	840	216	540	2,596
1978	1,000	840	228	630	2,698
1979	1,000	840	240	720	2,800
1980	1,000	840	240	810	2,890
1981	1,000	840	240	900	2,980
1982	1,000	840	240	990	3,070
1983	1,000	840	240	1,080	3,160
1984	1,000	840	240	1,170	3,250
1985	1,000	840	240	1,260	3,340
1986	1,000	840	240	1,350	3,430
1987	1,000	840	240	1,440	3,520
1988	1,000	840	240	1,530	3,610
1989	1,000	840	240	1,620	3,700
1990	1,000	840	240	1,710	3,790
1991	1,000	840	240	1,800	3,880
1992-2036	1,000	840	240	1,800	3,880

[1] These schedules apply to the High Line and its two variations. For the Coastal Line and Long Tunnel Line, the Southern California deliveries start at 306,000 acre-feet and build up only to 1,224,000 acre-feet in 1991, while the total supplied to Southern Kern County is increased 576,000. It is assumed that this results from the elimination of the Antelope Valley-Mohave Desert service area, the elevation of which is not reached by the Coastal Line and Long Tunnel Line.

SOURCE: State of California, Department of Public Works, Division of Water Resources, "Program for Financing and Contracting the Feather River Project as the Initial Unit of the California Water Plan," Table 17.

[1] *Water Utilization and Requirements of California* (preliminary draft), October, 1954.

[2] *Ibid.*, page 2-2.

The estimates of ultimate requirements in Bulletin No. 2 were made without reference to water cost or the ability of water users to pay.

> It is believed that the cost of water will not be a limiting factor in ultimate development of the water resources of California. * * * It is indicated that urban communities will always be able and willing to pay the cost of water to meet their municipal needs. Furthermore, it is considered probable that under pressure of future demands for agricultural produce the water necessary for a greatly expanded irrigation development will be provided, at whatever cost may be required. * * * Many works financially infeasible today will undoubtedly be financed and constructed in the future. * * * [3]

In line with these statements, economic considerations are explicitly set aside in the bulletin in determining criteria for the irrigability of land.

While Bulletin No. 2 represents much valuable work and will be useful for many purposes, it does not in itself provide the data needed to evaluate a particular project planned for a particular time. Additional information is needed which is related specifically to the project, its time schedule, and its water prices.

Planning for the Feather River Project would be greatly facilitated by a determination by proper authority of the amounts of water to be allocated to each service area and by establishing a definite price policy for water sales. Further detailed study of these matters will be required for more realistic estimates of probable water sales and for estimates of the financial outcome of the project.

TABLE II

FEATHER RIVER PROJECT

AVERAGE WATER REVENUES USED IN FINANCIAL ANALYSIS

(Dollars per acre-foot)

Financial Analysis	Feather River Project Aqueduct	San Joaquin Valley		Alameda, Santa Clara, and San Benito Counties	Southern California
		Fresno, Kings, and Northern Kern Counties	Southern Kern County		
1	Delta to Barrett Reservoir	$8.00	$9.00	$22.50	$45.00
2	Delta to San Bernardino	7.00	8.00	20.00	35.00
3	Delta to Castaic	7.00	8.00	17.50	25.00
4	Coastal Line to Castaic	8.00	9.00	20.00	45.00
5	Long Tunnel Line to Castaic	8.00	9.00	20.00	35.00

SOURCE: State of California, Department of Public Works, Division of Water Resources, "Program for Financing and Constructing the Feather River Project as the Initial Unit of the California Water Plan," p. 51.

[3] *Ibid.*, pages 1-53 and 1-54.

SECTION IV

DEMAND FOR PROJECT WATER IN SERVICE AREAS

In the areas which could be served by the aqueduct, the rate at which water sales will develop and contribute revenues to the project is of great importance. When it was found that the Feather River Project report had not been based on studies of the rate of development in the service areas, the problem became one not of review but of new research on water demand.

The areas which could be served with water from the project are vast and represents a wide variety of conditions. Within the limits of time and funds available, it was possible to investigate only selected parts of the water demand problem and to cover these in a general way. It is, therefore, highly desirable that further study of the water demand problem be made.

The demand for irrigation water is sensitive to water price and other economic factors affecting the profitability of the various irrigated crops. In some areas it was not possible to undertake an analysis sufficiently thorough to permit an estimate of irrigation water demand. Only where the situation is relatively simple and the answer clear-cut were quantitative estimates of irrigation demand made. It was assumed, on the other hand, that cost would not restrict the use of Feather River Project water in urban communities, and estimates of future demand based on population growth in the principal urban areas were made.

Among the possible service areas of the Feather River Project, the one designated Feather River Water Service Area is unique in that it is not served by the aqueduct but by diversion of water from the Feather River. In calculating the amount of water which would be available in the Sacramento-San Joaquin Delta for use in the aqueduct, an allowance for the ultimate needs of this area under full development was made. Appropriate analyses were made by the Division of Water Resources, and they were reviewed and checked against information available from the United States Bureau of Reclamation. A brief field examination of the area was also made.

San Joaquin Valley Service Area

The first area to which Feather River Project water could be delivered is the important west side [1] of the San Joaquin Valley. The proposed service areas are shown in Figure 2. For purposes of analysis, it is convenient to distinguish four separate units in this area: (1) West Side,[1] in western Fresno and Kings Counties, containing the irrigated lands of the Westlands Water District, Panoche Water District, and San Luis Water District; (2) Antelope Plain, an undeveloped area from Kettleman City to McKittrick; (3) Maricopa-Wheeler Ridge, a partially irrigated area south of Bakersfield; and (4) Semitropic Ridge, a partially irrigated area west of the proposed Shafter-Wasco Project.

The Feather River Project report shows that water deliveries to the San Joaquin Valley would begin in 1959, three years after the project is begun. A total of 600,000 acre-feet is shown as the initial delivery, increasing to 1,840,000 acre-feet in 1973. With the Coastal Line and the Long Tunnel Line, additional quantities are indicated for the southern portion of the area, bringing the total delivered to 2,416,000 acre-feet in 1991.

With these large quantities involved, it is obvious that the San Joaquin Valley will play a very important part in the project and have a great effect on its financial results.

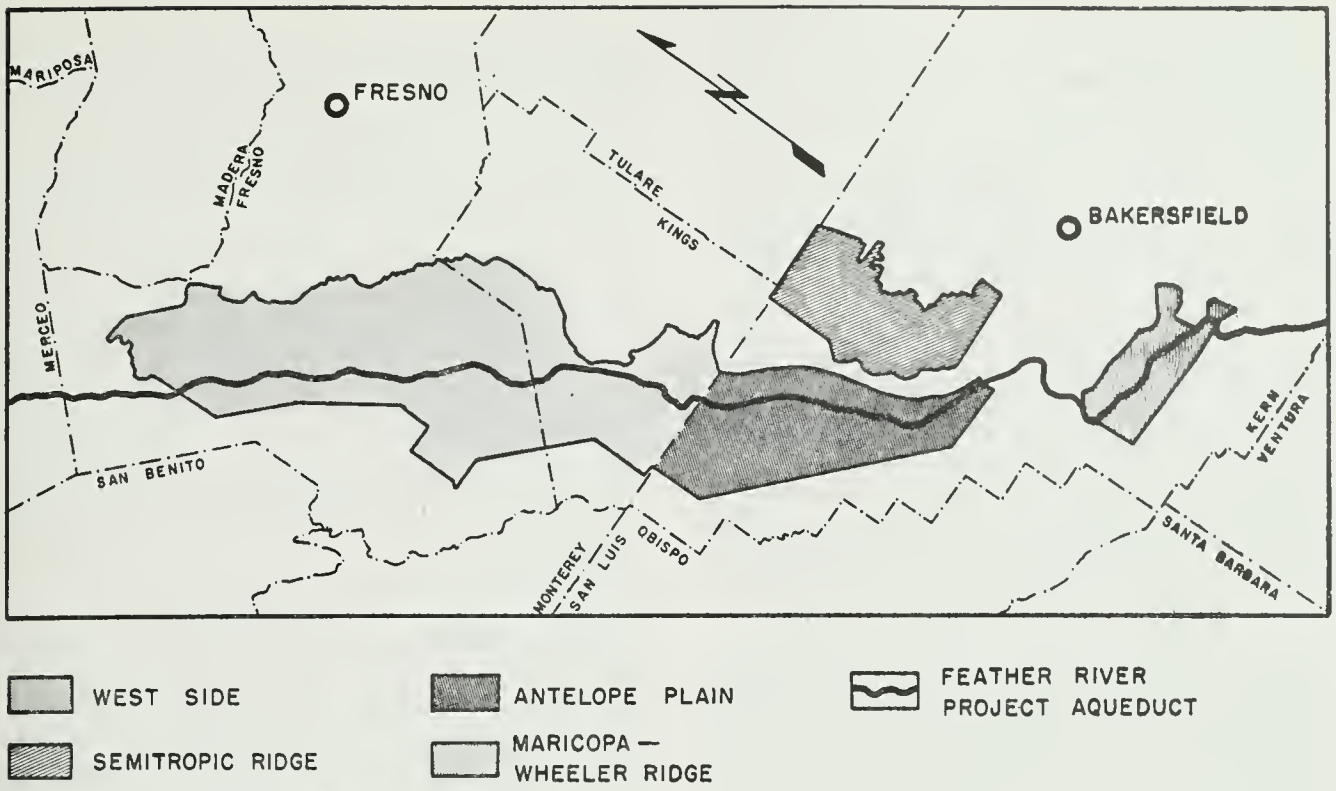
In the financial analyses in the Feather River Project report, average water revenues from $7 to $9 per acre-foot are indicated for water delivered in the San Joaquin Valley. It is therefore necessary to study the area to determine whether the scheduled quantities could be sold to produce these revenues.

Since urban developments in the west side of the San Joaquin Valley are very minor factors in the water use pattern of the area, and are expected to remain so, attention was focused on potential demand for irrigation water. Fortunately, the area is relatively homogeneous with respect to soils and climate; large acreages presently under irrigation serve as indications of what may be expected to develop. A large area had to be surveyed in a short time, but it is believed that the results of the survey are sufficiently accurate to provide useful conclusions for Feather River Project planning.

Potential Irrigable Land. The water deliveries stated in the Feather River Project report are based upon the analysis of water requirements in State Water Resources Board Bulletin No. 2. Unfortunately, because the acreage and water requirements figures of this publication are stated for hydrographic units, the boundaries of which do not coincide with the service area delineated in the Feather River Project report; a simple comparison is not possible.

Moreover, since Bulletin No. 2 defines irrigable land in a physical rather than in an economic sense, it is

[1] West Side (capitalized) commonly refers to the northern section of the west side of the San Joaquin Valley.



Source: Feather River Project Report — Plate 2.

FIGURE 2
FEATHER RIVER PROJECT—SAN JOAQUIN VALLEY SERVICE AREA

necessary to make an economic appraisal of potentially irrigable land in the service area.

It should be said that there is considerable justification for the physical definition of irrigable land in Bulletin No. 2, to determine the ultimate water requirements of the State.

However, such estimates of irrigable acreages cannot be used in measuring irrigation water requirements for the immediate or near future.

Investigation among informed persons in the San Joaquin Valley and an analysis based upon hypothetical farm budgets, reported later in this section, led to the conclusion that only classes 1 and 2 land should be considered irrigable and representative of a potential demand for water and that class 3 land can be farmed only with doubtful profitability under present cost-price conditions. Conceivably, poorer land may be developed eventually should the pressure upon land resources become greater than it is today—but such a possibility should not be given much weight in evaluating the economic feasibility of this project.

In determining the acreage of land that it might be economically feasible to irrigate, land classification maps of the University of California by Storie and Weir (1930) and more recent county land classification maps in the San Joaquin Valley were studied; and the areas were measured by planimeter for approximate determinations of the irrigable and unirrigable land.

No detailed land classifications are available for evaluating the quality of the land in the Antelope Plain; fortunately, the Fresno Office of the Bureau of Reclamation recently completed reconnaissance surveys in the area, and the results check closely with earlier work published in the Bureau of Reclamation Central Valley report [1] in the delineation of the irrigable land in the lower west side. This outline checks quite closely with the boundaries of the service area proposed in the Feather River Project report.

The results of the analysis of potentially irrigable land in the San Joaquin Valley (Table III) must be considered tentative and subject to further study, but they indicate the general magnitudes involved. The total service area comprises approximately 1,549,000 acres, of which 1,161,000 acres are in land classes 1 and 2, considered irrigable; and the balance of 388,000 acres are unirrigable or of doubtful irrigability. Of the total irrigable area, 499,000 acres are estimated to be irrigated today. It is further estimated that 78,000 acres will be occupied by farmsteads,

[1] U. S. Department of the Interior, Bureau of Reclamation, *Central Valley Basin*, Senate Document 113, 81st Congress, First Session, August, 1949.

roads, ditches, and by urban and suburban communities when full development is eventually reached. This is on the assumption that this west side area would develop an agricultural and urban economy substantially similar to the kind that exists in the San Joaquin Valley today. Based on this analysis, 584,000 acres of irrigable land are considered suitable for economic development if the price of water does not greatly exceed present costs of water to agriculture. This question will be considered further below.

Of the total acreage, a considerable block of irrigated land exists in the Westlands Water District, the Panoche Water District, and the San Luis Water District in the West Side, and another 190,000 acres are irrigable in western Fresno and Kings Counties. But the major potential irrigable area is in the Antelope Plain of western Kern County, consisting of 267,000 acres. About half of the Semitropic Ridge appears capable of irrigation, about 55,000 acres, and the bulk of the Wheeler Ridge area, another 72,000 acres.

Water Balance and Overdraft Situation. It has been indicated that less than half the irrigable land in the Feather River Project service area of the San Joaquin Valley is presently being irrigated. With few exceptions the irrigation water supply is based upon pumping from ground water. These irrigated areas are in greatest need of supplemental water at the present time, in view of increasing costs of pumping due to falling water levels. This is reflected in a large and worsening overdraft situation.

In Bulletin No. 2, State Water Resources Board, the estimate of existing overdraft is 750,900 acre-feet in the three hydrographic units in question, distributed as follows:

Hydrographic Unit	*Present Annual Overdraft*
No. 36. Antelope Plain	11,800 acre-feet
No. 37. Kern	214,900 acre-feet
No. 54. West Side, San Joaquin Valley	524,000 acre-feet
Total	750,900 acre-feet

It is to be noted that these hydrographic units are larger than the proposed service area and that these figures may overstate the extent of the existing overdraft. It is appropriate, then, to turn to a somewhat more detailed discussion of the ground water and pumping situation in the several developed irrigation economies of the San Joaquin Valley which represent a potential demand for supplemental surface water.

West Side (Western Fresno and Kings Counties). This area comprises essentially the irrigated land of the Westlands Water District, the Panoche Water District, and the San Luis Water District. Since heavy irrigation began, water levels have dropped nearly continuously in this area. The rate of decline has averaged about 25 feet annually over the last 10 years because the groundwater resource has continued to be exploited faster than it could be replaced. In 1954, the pumping lift averaged 423 feet, and the drop is continuing.

In its feasibility report on the San Luis Unit, the Bureau of Reclamation estimated that the annual ground water withdrawal was about one million acre-feet during the 1950-51 season, of which approximately 700,000 acre-feet was consumptively used.[1] The long-term recharge from stream seepage and subsurface inflow is about 213,000 acre-feet annually, consisting of 32,000 acre-feet annually from west side streams, and about 181,000 acre-feet annually as deep underground flow from the east side of the San Joaquin Valley. This is the considered safe yield of this area under present conditions—much less than the present use.

The overdraft is estimated at 540,000 acre-feet annually. This checks closely with the estimate of 524,200 acre-feet in hydrographic unit No. 54 in Bulletin No. 2. Since more land has been developed and put into irrigation over the last four to five years, the overdraft is probably greater today.

[1] U. S. Department of the Interior, Bureau of Reclamation, Region 2, *San Luis Unit, Central Valley Project, California: A Report on the Feasibility of Water Supply Development,* Sacramento, California.

TABLE III

ESTIMATED PRESENT AND POTENTIAL LAND USE

SAN JOAQUIN VALLEY SERVICE AREA

(Thousands of acres)

Service areas	Gross area	Irrigable land	Farmsteads, urban land, roads, and ditches	Net productive irrigable land	Presently irrigated land	Potentially irrigable land
Fresno County	633	511	34	477	380	97
Kings County	263	144	10	134	41	93
Kern County	653	506	34	472	78	394
Antelope Plain	321	291	20	271	4	267
Semitropic Ridge	211	121	8	113	58	55
Wheeler Ridge	121	94	6	88	16	72
Total	1,549	1,161	78	1,083	499	584

SOURCE: Stanford Research Institute.

Antelope Plain. The minor development of irrigation in the Antelope Plain area consists almost solely of a few thousand acres around Devils Den irrigated by pumping. In Bulletin No. 2, the estimate of the present overdraft is 11,800 acre-feet.

Not much is known about this large and potentially fertile irrigable area, but it is believed that underground supplies are limited and that the quality of water may in a considerable portion of the area be unsuitable for irrigation. There has been no movement toward bringing these lands into production, and there is the possibility that irrigation may depend almost altogether on imported water.

Central Kern County. A number of large irrigated blocks of land exist in this section of the county with severe overdraft underground water conditions. The existing overdraft condition will be relieved to some extent by supplemental water brought in by the Friant-Kern Canal of the Central Valley Project. Construction of distribution works is commencing this year in the Shafter-Wasco Irrigation District, which will make available about 89,000 acre-feet of supplemental water annually.

The critical situation in the Arvin-Edison Water Storage District will be improved if the negotiations now in progress for an exchange of water can be agreed upon between the Arvin-Edison District and interests in the lower Kern River on a mutually acceptable basis to these two groups and the Bureau of Reclamation. Should such an agreement be worked out, a variable supply of 40,000 to 200,000 acre-feet annually could be obtained from the Central Valley Project, a supply that could materially reduce the existing overdraft, but would still leave a substantial overdraft.[1]

Indicated service areas for the Feather River Project in central Kern County are the Maricopa-Wheeler Ridge area and the Semitropic Ridge area, Just west of the Shafter-Wasco Project. The overdraft is very severe in these two areas, particularly in the Wheeler Ridge area, where the water level has been dropping over 30 feet annually during recent years. In the Semitropic Ridge area, pumping lifts have not been so great as at Wheeler Ridge, and lifts have been increasing about seven feet per year.

Present Costs of Irrigation Water. In evaluating potential consumption of supplemental water for irrigation, it is essential to consider present and prospective costs of obtaining water and the capacity of agriculture to pay for such supplies. The Feather River Project Report, as indicated previously, does not include an economic analysis of the problem, which is essential for an evaluation of the potential demand for irrigation water. The problem has been considered in this report insofar as time and available resources have permitted. The results must be considered tentative, and the whole subject should be investigated thoroughly in any further consideration of satisfactory water prices in the areas to be serviced by the Feather River Project.

In the following paragraphs, the pumping situation and present pumping costs are summarized for the existing irrigated areas on the west side of the San Joaquin Valley.

Farm Pumping Situation. In the Westlands Water District, wells to tap the ground water basin are drilled to depths of 1,500 to 2,000 feet. Many have been drilled beyond these depths. At the present time, the cost of drilling wells and of casings, motors, and distribution pipes is as high as $60,000 at these greater depths. These wells usually irrigate a section (640 acres) of land. They are operated by electrically driven pumps of 100 to 300 horsepower.

Besides the sharply declining water table, which has been responsible for frequent lowering of bowls and deepening of wells, the area has been afflicted by the loss of pumping equipment due to subsidence and electrolysis problems. Besides making investments more uncertain, these conditions have reduced the life of wells and equipment and have tended to increase the fixed costs of pumping water.

Data supplied by the Pacific Gas and Electric Company indicate that power costs averaged $6.18 per acre-foot in 1954 in this area. With amortization of investment costs estimated at $2.88 per acre-foot, the costs of pumping totaled $9.06 per acre-foot. (See Table IV.) It is necessary to emphasize that these costs increase from season to season, owing to the rapidly declining water level. On the other hand, there are considerable differences in well depths and pumping levels throughout the West Side, which put some operators in a more favorable position than others. Moreover, since power charges are affected by pumping efficiency and the load factor, farmers in a position to increase these by maintaining good equipment and by proper planning of irrigation may economize in pumping to a greater degree than those not similarly placed.

Land in the Maricopa-Wheeler Ridge area is of excellent quality, and a considerable expansion in irrigated acreage is possible. The pumping lift averages about 400 feet and has been increasing in recent years at the rate of 30 feet annually over a good portion of the area. The overdraft is estimated at 80,000-90,000 acre-feet per year.[2]

The pumping situation in the Wheeler Ridge area is even more serious than on the West Side. The lift has been increasing more rapidly from year to year, and the costs of developing water supplies are high. A well is required for approximately every quarter

[1] Allen Bottorff, Water Problems of Southern San Joaquin Valley and Their Suggested Solution. Address delivered to the Commonwealth Club, San Francisco, October 27, 1955.

[2] Forrest Frick, Chairman of the Kern County Water Association. Statement to Hearing of State Assembly, April 28, 1955.

section (160 acres) in this area. Thus, proportionately, amortization costs per acre-foot of water applied are higher in relation to power costs than in the other irrigated service areas in the San Joaquin Valley. At an average lift of 400 feet, it is estimated that direct power costs are $5.85 and fixed charges are $6.60, a total of $12.45 per acre-foot of irrigation water applied.

TABLE IV

ESTIMATED COSTS OF PUMPING WATER ON FARMS

SAN JOAQUIN VALLEY SERVICE AREA

Service area[2]	Cost of pumping water[1] per acre-foot		
	Power cost	Depreciation	Total cost
West Side (hydrographic unit 54)	$6.18	$2.88	$9.06
Antelope Plain (hydrographic unit 36)	--	--	--
Semitropic Ridge (hydrographic unit 37)	2.92	2.20	5.12
Wheeler Ridge (hydrographic unit 37)	5.85	6.60	12.45

[1] Based on approximate average pumping lifts: West Side, 425 feet; Semitropic Ridge, 200 feet; Wheeler Ridge, 400 feet.
[2] Hydrographic units refer to State Water Resources Board Bulletin No. 2.

The overdraft in the Semitropic Ridge area immediately west of the Shafter-Wasco project has also been increasing as more land has been brought under pumping in recent years. Here, however, the pumping lift may average about 200 feet and the water table has been dropping about seven feet annually. With a spacing of one pump every half section (320 acres), it is estimated that water costs are averaging about $5.12 per acre-foot, comprising about $2.92 for power costs and $2.20 for depreciation charges.

It should be noted that these estimates of the costs of water obtained by pumping from underground levels do not include the costs of irrigating crops, but only the costs of making the water available. For comparison, it may be observed that the Bureau of Reclamation is delivering water from the Friant-Kern Canal at canalside at the rate of $3.50 per acre-foot for class 1 water and $1.50 per acre-foot for class 2 water. It is not known what the costs of distributing water to the farm are. In the Factual Report on the Shafter-Wasco Irrigation District,[1] it was estimated that the distribution system would cost $8.80 per acre annually which would be equivalent to $3.13 per acre-foot assuming the application of 2.84 acre-feet of water per acre. This represents a relatively cheap distribution system, considerably below the usual cost for such structures. Costs of operation and maintenance would be additional.

[1] U. S. Department of the Interior, Bureau of Reclamation, Region 2, *Factual Report: Shafter-Wasco Irrigation District, Central Valley Project, California,* Fresno Operations Office, Fresno, California, January, 1953, p. 34.

Economic Limit to Water Charges. To evaluate the effect of water prices on the demand for water and the effect on the agricultural economy in areas with a potential demand for supplemental water, it is necessary to know not only present costs of water but the economic limits of what can be charged for project water in these areas. In the absence of an economic analysis in the Feather River Project report, it was necessary to make a limited study of the capacity of agriculture to pay for water, in order to evaluate the water prices postulated in the financial analyses of the report.

Analysis of Capacity to Pay for Water. The type of analysis made is customary for this purpose. It consists of a determination of the net income available for compensating management and to pay for water. Net income is projected based on long-term cost-price relationships and cropping patterns presumed to prevail during the life of the project.

The Bureau of Reclamation ordinarily computes the capacity to pay for water by determining net farm income and deducting a "family living exemption" large enough to compensate the operator for the equivalent of a year's labor at going rates for comparable labor. Under the bureau's type of analysis, the capacity to pay turned out to be only about one dollar per acre-foot less.

In making the analysis, it was assumed that the present structure of prices and costs will continue into the future under the high-level business conditions that have prevailed in the postwar period. Farm inputs have been priced at the current levels of recent years. Prices received by farmers for commodities produced were based upon the average of the last ten years, 1945-54. These cost-price relationships are equivalent to a ratio of about 87 percent of parity, a relationship probably not too unrealistic as a reflection of long-term price relationships between agricultural and nonagricultural commodities. Farm cost data were developed from the management studies of the University of California Extension Service, and the budget studies of the Bureau of Reclamation are to be found in reports on various irrigation districts located along the routes of the Delta-Mendota and Friant-Kern canals.[2]

Projected Cropping Pattern. Very important in the analysis of the capacity to pay for water is the cropping pattern assumed to exist in the long run under project conditions. In State Water Resources Board Bulletin No. 2 are projected future cropping patterns for the various hydrographic units. These units were developed essentially for the purpose of measuring ultimate water requirements.

[2] In most instances, the farm cost budgets of the Bureau of Reclamation studies had to be adjusted upward to reflect the index of 271 percent of parity typical of recent years.

The cropping patterns are based on a state-wide cropping pattern projection [1] and are broken down into separate cropping patterns for hydrographic areas within the State and the San Joaquin Valley. These cropping patterns were accepted as satisfactory, though there was no complete agreement with the projections. Table V shows the "ultimate" cropping patterns for the three hydrographic units corresponding to the West Side, the Antelope Plain, and the combined Semitropic Ridge and Wheeler Ridge areas.

Evaluation of Cropping Patterns. There are many imponderables in developing and evaluating crop pattern projections. The answers depend not only upon future prices dictated by business conditions but upon governmental policy in price supports and in acreage and marketing controls.

It is felt that the pattern projected in Bulletin No. 2 overemphasizes cotton production in the future land use of the valley. There is a possibility, however, that by the time the Feather River Project is completed, federal policy may avoid acreage controls in favor of price supports low enough to permit free prices to operate in the allocation of resources in the production of cotton in the United States. In such an eventuality, the states of Texas, Arizona, and California, which produce cotton under large-scale mechanized conditions, would have a competitive advantage, with the resulting shift of cotton production to these western states to an even greater degree than has occurred in the last decade. Under these conditions, it is possible that the projected cropping patterns of Bulletin No. 2 might become a reality.

It seems also that the state's cropping pattern may not have sufficiently emphasized irrigated pastures as an important base for the livestock economy of the future. There would seem to be good reasons also for enlarging the proportion of the acreage allocated to truck crops. Livestock and vegetable products have tended to become an increasingly important portion of the diet of American consumers. With a rapidly growing population, it would appear that more land will be needed for forage and truck crops to meet this growing demand.

In spite of these possible shortcomings in the cropping patterns projected in Bulletin No. 2, the production cost budgets were based upon them. It was realized that the importance given to cotton in the land use pattern would tend to make the resulting net income position of the irrigation economies of the San Joaquin Valley more favorable—nevertheless, these results do not significantly affect the estimates of what agriculture can pay for water.

TABLE V

ULTIMATE CROPPING PATTERN PROJECTED BY STATE WATER RESOURCES BOARD

SAN JOAQUIN VALLEY [1]

Crop	West Side (hydrographic unit 54)	Antelope Plain (hydrographic unit 36)	Semitropic Ridge and Wheeler Ridge (hydrographic unit 37)
Cotton	53%	58%	60%
Alfalfa	12	11	13
Pasture	4	5	7
Hay and grain	5	6	4
Field crops	13	8	1
Truck crops	5	8	6
Orchard and grapes	7	4	7
Miscellaneous	0	0	2
Total	100%	100%	100%

[1] Derived from Table 7-10 of State Water Resources Board Bulletin No. 2, "Water Utilization and Requirements of California," Sacramento, California, October, 1954.

[1] The basic state-wide cropping pattern projection was developed by Professor David Weeks of the Giannini Foundation, University of California, and is to be published as Appendix A of Bulletin No. 2. Professor Week's projection represents an analysis of national trends in production and consumption affecting the agriculture of the entire State of California.

Net Farm Income, Excluding Water Costs. Net farm income available, prior to the payment of water costs and compensation for management, was computed for class 1, 2, and 3 land. The results are shown in Table VI in terms of available net farm income per acre-foot of irrigation water applied. The data reveal, what has been supported by experience in the irrigated areas on the west side of the valley, that the cultivation of class 3 land is of doubtful economic feasibility. Net farm income of class 3 land ranges between approximately $9 to $11 per acre-foot, which is less than the total cost of pumping in the Wheeler Ridge area, and barely above it in the West Side (Table IV). Therefore, there is no economic incentive to develop class 3 land for irrigation, which explains why only the best land in these areas is being utilized.

Feasibility of Projected Water Prices. The crucial question is whether the high-quality lands can support a demand for supplemental water from the Feather River Project based upon a water price of $7 to $9 per acre-foot at canalside. It would seem to be quite clear that class 3 land could not be an economic factor, especially when it is necessary to consider the additional costs of distributing the water from canalside to the farmer's headgate. It would not be unreasonable to assume that distribution costs would run about $8 per acre-foot in this area. Thus, a water cost of $15 to $17 does not appear to be out of the question. On class 2 land, with an estimated net farm income of about $28 per acre-foot before water costs, a net income after water costs of $11 to $13 per acre-foot should make the irrigation of land of this quality or better a feasible economic venture.

Schedule of Potential Water Deliveries. As the final step in this analysis, it is necessary to consider the schedule of water deliveries in the San Joaquin Valley as illustrated in the financial analyses of the

TABLE VI

ESTIMATED NET FARM INCOME BEFORE WATER COSTS
SAN JOAQUIN VALLEY SERVICE AREA

Service areas	Farm delivery demand (acre-foot per acre[3])	Net farm income[1] before water costs (per acre-foot)		
		Class 1 land[2]	Class 2 land[2]	Class 3 land[2]
West Side (hydrographic unit 54)	2.71	$34.67	$27.70	$10.63
Antelope Plain (hydrographic unit 36)	2.67	36.16	28.37	11.06
Semitropic Ridge (hydrographic unit 37)	2.84	35.86	28.10	8.80
Wheeler Ridge	2.84	35.86	28.10	8.80

[1] Excludes costs of family living.
[2] Bureau of Reclamation land classification.
[3] Based upon consumptive water use estimates by State Water Resources Board, assuming an irrigation efficiency of 70 percent and irrecoverable losses 25 percent of percolation losses.

Feather River Project report. It was pointed out previously that this schedule was designed to serve areas of need first and that, in view of the fact that water demand will exceed supply made available by the project, the choice between areas would probably be a "first-come first-served" basis.

Irrigable Land Area. The discussion so far has indicated that undoubtedy only the best lands, classes 1 and 2, can be expected to be farmed feasibly under existing costs of procuring ground water, which provides cheaper sources of water than can be obtained alternatively. The fact that irrigation of class 3 land is of doubtful economic feasibility is supported by farming experience in the west side area, by the feasibility reports of the Bureau of Reclamation, and by the budget analysis of the previous section.

To summarize, of the estimated 1,549,000 acres in the San Joaquin Service Area, 1,161,000 acres are irrigable. Farmsteads, urban communities, roads, and ditches are estimated to require 78,000 acres at full development. The net productive irrigable area thus consists of 1,083,000 acres, of which 499,000 acres are presently irrigated and 584,000 are potentially irrigable. (See Table III.)

Unit Water Requirements. In the study of the water requirements of California in Bulletin No. 2 estimates were made of water requirements of crops in the various hydrographic units covering the service areas in the San Joaquin Valley. These were based upon the accepted Blaney-Criddle method. The results have been checked and have been found satisfactory in estimating average annual water deliveries.

The total consumptive requirements of crops, as estimated in Bulletin No. 2 and the Bureau of Reclamation feasibility studies, are in very close correspondence. The crop irrigation requirements of the state are lower than those of the Bureau because a higher effective use of precipitation was assumed. The Bureau's estimate is more conservative and tends to reflect requirements under drought conditions. Each of these approaches obviously has its special uses in planning the many features of a water project.

Water Management Under Project Conditions. In estimating potential supplemental irrigation water requirements, it should be recognized that some pumping will be continued or carried on in every irrigated area insofar as the quality of water will permit. In fact, pumping will be necessary to reduce the drainage problem and will serve to reduce the cost of water to the irrigation districts. In the presently irrigated districts of the projected service areas where the overdraft situation has been responsible for increasing and serious water cost problems, it will be desirable to restore ground water levels in some degree for the purpose of reducing pumping costs. This can be done by restricting pumping volume to less than recoverable percolation losses over a period of a few years. Once the groundwater level has been restored to a more economical pumping lift, pumping can be increased until a safe yield situation has been reached. This can be achieved in each of the districts, but it will require some control of pumping by individuals or by the acquisition and operation of pumping facilities by the districts concerned.

The situation described is being planned for in the West Side water districts in anticipation of the construction of the San Luis Unit of the Bureau of Reclamation. The same measures would apply for the construction of the Feather River Project.

Water Management Under the San Luis Unit. It is of interest to describe briefly the way in which the Bureau of Reclamation proposed to manage the water supply in the three West Side irrigation districts comprising the San Luis Unit. Total annual water requirements are estimated at 1,666,000 acre-feet, percolation losses at 540,000 acre-feet, and the crop irrigation requirements at 1,126,000 acre-feet. About 454,000 acre-feet would be recoverable irrigation losses from the 540,000 acre-feet pumped directly from ground water into the distribution system.

The annual recharge in the ground water basin, estimated at 664,000 acre-feet, is derived from recoverable irrigation losses and an annual natural inflow of 213,000 acre-feet. A discharge of 127,000 acre-feet would be drained off along the eastern edge of the service area.

The annual import of water into the district would consist of 1,251,000 acre-feet, including crop irrigation requirements and irrecoverable losses. To reach this stabilized long-term situation, the water table would be built up over a period of time until the pumping lift would be stabilized at about 250 feet. A similar approach to the problem could be effected in the other potential service areas under project conditions.

Unit Supplemental Requirements. Under stabilized conditions, it is believed possible to maintain the volume of supplemental surface water deliveries at a level equal to the crop irrigation requirements and the irrecoverable percolation losses. In making estimates of such imported water requirements, it is assumed that irrigation efficiency is 70 percent and that 25 percent of percolation losses cannot be recovered. These estimates appear reasonable and are consistent with irrigation experience in the Central Valley.

The various water utilization rates are shown in Table VII on an acre-foot per acre basis. The estimated supplemental irrigation requirements rates for most areas are slightly below but not significantly different from this in State Water Resources Board Bulletin No. 2.

Total Supplemental Requirements. The total supplemental water requirements for the various parts of the San Joaquin Valley Service Area are based upon the acreages of presently irrigated or potentially irrigable land multiplied by the utilization rates per acre. The resulting finding is that the entire service area delineated in the Feather River Project report has a potential water demand, at full development, of 2,369,000 acre-feet, composed of supplemental irrigation requirements of 2,291,000 acre-feet and an additional requirement of 78,000 acre-feet for other uses, farmsteads and urban communities. (See Table VIII.)

These estimated total water requirements compare with the 1,840,000 acre-feet suggested for delivery in the Feather River Project report, and indicate that the potential demand for irrigation is in excess of deliveries by approximately half a million acre-feet. The supply-demand relationship is similar in the various parts of the service area. In Fresno and Kings Counties, the demand for water is estimated at 1,331,000 acre-feet, compared with proposed maximum deliveries of 1,000,000 acre-feet; and in Kern County, the demand for 1,038,000 acre-feet compares with proposed deliveries of 840,000 acre-feet.

The fact that the potential demand exceeds the supply for delivery emphasizes the suggestion in the Feather River Project report that areas with an existing need might be served first. Estimates of potential demand indicated a probable supplemental requirement of 1,062,000 acre-feet on land presently irrigated, where an urgent need for outside water exists. The bulk of this demand, 890,000 acre-feet, exists in the West Side district. The indicated total demand of 172,000 acre-feet estimated to exist in Kern County may be as high as 200,000 acre-feet, because more land has been brought under irrigation since the year on which this estimate is based.

TABLE VII

IRRIGATION WATER REQUIREMENTS

SAN JOAQUIN VALLEY

(Acre-feet per acre)

Service areas	Crop irrigation requirement[1]	Applied irrigation requirement[2]	Supplemental irrigation requirement[3]
Fresno County	1.93	2.71	2.12
Kings County	1.93	2.71	2.12
Kern County			
Antelope Plain	1.87	2.67	2.07
Semitropic Ridge	1.99	2.84	2.20
Wheeler Ridge	1.99	2.84	2.20

[1] Weighted mean based on the crop irrigation requirements and ultimate cropping patterns projected by the State Water Resources Board, Bulletin No. 2.
[2] Irrigation efficiency of 70 percent.
[3] Irrecoverable losses of 25 percent.
SOURCE: Stanford Research Institute.

TABLE VIII

ESTIMATED SCHEDULE OF SUPPLEMENTAL WATER REQUIREMENTS

SAN JOAQUIN VALLEY SERVICE AREA

(Thousands of acre-feet)

Year	Fresno County			Kings County			Kern County			Grand Total
	Irrigation	Other	Total	Irrigation	Other	Total	Irrigation	Other	Total	
1	232	7	239	50	2	52	168	7	175	466
2	333	10	343	78	3	81	268	10	278	702
3	474	14	488	110	4	114	377	14	391	993
4	616	19	635	142	6	148	486	19	505	1,288
5	757	22	779	173	7	180	595	22	617	1,576
6	858	26	884	201	8	209	695	26	721	1,814
7	915	28	943	221	8	229	770	28	798	1,970
8	969	30	999	238	9	247	837	30	867	2,113
9	980	31	1,011	248	9	257	879	31	910	2,178
10	990	32	1,022	258	10	268	921	32	953	2,243
11	998	33	1,031	265	10	275	954	33	987	2,283
12	1,004	34	1,038	271	10	281	979	34	1,013	2,332
13	1,010	34	1,044	277	10	287	1,004	34	1,038	2,369

SOURCE: Stanford Research Institute.

Evaluation of State Delivery Schedule. Crucial to the sound planning of the project facilities and to meeting the needs of future buyers of water are the estimates of the probable buildup in water requirements in the various service areas. In the financial analysis of the Feather River Project report, it was assumed that water deliveries in the San Joaquin Valley would begin with delivery of 600,000 acre-feet in the first year after the aqueduct is completed and would build up gradually over a period of 15 years to a maximum delivery of 1,840,000 acre-feet. The report does not specify whether developed and undeveloped areas would be delivered water simultaneously, or whether delivery to irrigable but presently undeveloped lands will be delayed for some time.

Price levels for farm products will be one of the most important factors in determining the rate at which new land is developed and distribution facilities for project water are provided. As long as there are favorable profit potentials in irrigated agriculture of the type adapted to this area, there are powerful forces leading to speedy development. Modern methods of cultivation and large-scale equipment for preparing the land make it possible to operate large farms. The west side of the San Joaquin Valley is characterized by large-scale operations supported by substantial financial resources. It has been assumed in this analysis that the cost-price relationships typical of the full employment economy which has existed in recent years will continue after the project is built.

Under these favorable conditions, there are good reasons to believe that water deliveries in the San Joaquin Valley would increase rapidly if sufficient water were available. In the large presently irrigated areas, the farms are already developed and able to use the water immediately. The need for supplemental water in these areas has already been described. The organizations needed to purchase and distribute project water already exist for very large acreages and are being formed for others. As soon as distribution lines from the aqueduct could be built, these areas would provide a large market for water.

The experience of the Bureau of Reclamation in the east side of the San Joaquin Valley is indicative of what may be expected. The Madera-Friant-Kern Canal was completed in June, 1951, and a full exchange of water with the Delta-Mendota Canal became effective in 1952. Average ultimate deliveries of class 1 and 2 water had been estimated at 1.4 million acre-feet. The Bureau now has contracts with 15 irrigation districts. Over one million acre-feet of water were sold in 1955, four years after completion of the project, but up to 1.5 million acre-feet of water could have been sold had a sufficient supply been available. Prior to the Bureau's project in this area, four irrigation districts were obtaining surface water and had distribution facilities. Several districts were based on pump irrigation. Expansion in the area required development of new lands, the conversion of dryland farms to irrigation, the formation of new irrigation districts, and the construction of distribution systems. Considerable land was put under pump irrigation in anticipation of the approach of the canal and was soon in need of supplemental water because of falling water levels. Rapid as the expansion of deliveries has been, it appears that construction of distribution facilities has been a bottleneck. It is anticipated that the distribution works will be finished in 1956, with the completion of the system in the Shafter-Wasco Irrigation District. Thus the delivery of the estimated ultimate volume of supplemental water, assuming that an adequate supply is available, should be achieved in 1956, after a five-year period of development.

While experience in development of irrigation in areas outside the San Joaquin Valley may not be as pertinent because of different conditions it does provide useful indications. The situation in the Bureau of Reclamation's Columbia Basin Project may be cited for illustration. Almost without exception, development there involved the development of raw land.

The first tract to be served from the Columbia Basin Project was 60,000 acres. At the end of five years, 70 percent of this land was under irrigation. In the interim, however, service had been extended to other tracts, bringing the total area served to 300,000 acres. In the fifth year, 55 percent of this total area was irrigated. It is now expected that full development of individual tracts will be achieved in 9 or 10 years after they are first served.

Judging from these experiences of the Bureau of Reclamation, one may conclude that under modern conditions it should be possible to reach maximum deliveries on presently irrigated land within about five years and that it should be possible to reach ultimate deliveries on undeveloped irrigable lands within about 10 years after water is made available. However, even these estimates may be too long under favorable economic conditions, because there will be a strong incentive to anticipate the availability of supplemental water by beginning the construction of distribution facilities simultaneously with the construction of the main aqueduct. At the same time, farmers may be expected to begin developing the new land and possibly even sinking wells in anticipation of supplemental water. Thus, in effect, the development period may be considered to include the time required to construct the aqueduct, which is estimated to be three years in the Feather River Project report.

A Proposed Delivery Schedule. Based upon the maximum potential growth in water requirements in the San Joaquin Valley service area, Table IX pre-

TABLE IX

ESTIMATED DEMAND FOR PROJECT WATER FOR IRRIGATION ON PRESENTLY IRRIGATED AND UNDEVELOPED LAND

SAN JOAQUIN VALLEY SERVICE AREA

(Thousands of acre-feet)

Year	Fresno County		Kings County		Kern County								Total three counties		
					Antelope Plain		Semitropic Ridge		Wheeler Ridge		Total				
	Irrigated	Undeveloped	Irrigated	Undeveloped	Irrigated	Undeveloped	Irrigated	Undeveloped	Irrigated	Undeveloped	Irrigated	Undeveloped	Irrigated	Undeveloped	Total
1	201	31	21	29	2	83	32	18	9	24	43	125	265	185	450
2	282	51	30	48	3	138	45	30	13	39	61	207	373	306	679
3	402	72	43	67	4	194	63	43	18	55	85	292	530	431	961
4	523	93	55	87	5	249	82	55	24	71	111	375	689	555	1,244
5	644	113	68	105	7	304	101	67	29	87	137	458	849	676	1,525
6	725	133	76	125	8	359	114	79	32	103	154	541	955	799	1,754
7	765	150	81	140	8	404	120	89	34	115	162	608	1,008	898	1,906
8	805	164	85	153	9	443	127	97	36	126	172	666	1,062	983	2,044
9	805	175	85	163	9	470	127	103	36	134	172	707	1,062	1,045	2,107
10	805	185	85	173	9	498	127	109	36	142	172	749	1,062	1,107	2,169
11	805	193	85	180	9	520	127	114	36	149	172	783	1,062	1,156	2,217
12	805	199	85	186	9	537	127	117	36	154	172	808	1,062	1,193	2,254
13	805	205	85	192	9	553	127	121	36	158	172	832	1,062	1,229	2,291

SOURCE: Stanford Research Institute.

sents a schedule of annual deliveries of supplemental water, assuming simultaneous initiation of deliveries in all areas, developed as well as undeveloped. The assumed build-up schedule of eight years for irrigated lands and 13 years for presently undeveloped lands after water starts flowing from the aqueduct is believed to be adequate. Deliveries in the first year are estimated at 466,000 acre-feet, compared with the deliveries of 600,000 acre-feet of the Feather River Project report, but the build-up is considerably more rapid. Under these conditions, the 1,800,000 acre-feet total shown in the Feather River Project report could be delivered in the sixth year, and peak deliveries of 2,369,000 acre-feet could be reached in the 13th year. If a plan of serving presently irrigated areas first were followed, it is obvious that the general build-up in deliveries could be considerably extended, depending upon the length of time that service to presently undeveloped areas is postponed.

Southern California Service Area

The Feather River Project report indicates two areas in Southern California which could be furnished supplemental water from the project aqueduct. These are the Antelope Valley-Mohave Desert area and the South Coastal area. To illustrate what could be supplied in these areas, the High Line route and its two variations show facilities to deliver about 600,000 acre-feet per year to the desert area and 1,200,000 acre-feet to the coastal region. The Coastal Line and the Long Tunnel Line do not reach the elevation of the Antelope Valley, and only 1,224,000 acre-feet are indicated as delivered by these lines. It is assumed that this is intended for the coastal region only.

In the financial analyses of the five different aqueduct possibilities, the first delivery of water in Southern California is shown in 1976. With the High Line and its two variations, the deliveries begin at 450,000 acre-feet and increase by 90,000 acre-feet annually until the total of 1,800,000 acre-feet is reached. With the other two aqueduct routes, deliveries start at 306,000 and increase by 61,200 acre-feet annually to the total of 1,224,000 acre-feet. The two parts of the Southern California area are discussed separately in the following paragraphs.

Antelope Valley-Mohave Desert. The outline of this water service area in the Feather River Project report includes some 550,000 acres divided between the Antelope Valley in Los Angeles County and the Mohave River basin in San Bernardino County. (See Figure 1.) In the Antelope Valley portion of this area, about 38,500 acres were irrigated in 1954, while about 3,800 acres are presently irrigated in the Mohave River Basin portion of the area. The total urban population of the area is approximately 31,000.

It is difficult to estimate future population growth in this area. The existing communities have grown rapidly in the last few years under the stimulus of nearby military installations and new industrial plants, the latter being chiefly extensions of the aircraft industry centered around Los Angeles. The highly specialized nature of the new activities makes it difficult to foresee the extent to which these activities will continue to expand over the period twenty years and more in the future and the extent to which other industries may come into the area. However, in

spite of these uncertainties it is possible to reach significant conclusions on the demand for Feather River Project water.

If the population were to increase to more than three times the present number and reach 100,000 by 1976, the resulting urban water requirement would be quite a small part of the volume scheduled in the Feather River Project report for delivery in that year. Allowing a gross daily per capita use of 150 gallons, the gross urban water requirement would be only about 17,000 acre-feet for the year. The scheduled delivery for 1976 is 144,000 acre-feet. It is thus clear that even allowing for substantial variations from the population figure used here, the urban demand would be relatively small. Even these figures are for gross urban requirements and make no allowance for the recapture of return flows to ground water, which would be substantial in this area. The net urban requirement on the water supply of the area would be even less than the figures used in the illustration.

From this example it is apparant that the only possible source of demand for water in the large quantities shown for this area in the Feather River Project report is irrigation. It is estimated that there are over 400,000 potentially irrigable acres in the service area, of which only 10 percent are now irrigated. This would, indeed, provide a large market for water if it could be made available at a price which farmers could afford to pay. The report indicates that average revenues from $25 to $45 per acre-foot, depending on the works constructed, would be required in Southern California to cover the cost of providing project water. It is clearly not economic to pay such costs, plus the expenses of local distribution, for irrigation water in the Antelope Valley-Mohave Desert Area.

The entire Antelope Valley, much of which is outside the indicated service area, has experienced a net overdraft on the ground water for many years, increasing from 74,000 acre-feet annually in 1930 to 168,000 in 1951. Over this period, the average pumping lift increased from 109 to 197 feet.[1] The lift is increasing about 5 feet per year. Pump test records of the Southern California Edison Company for this area show a weighted average pumping lift of 228 feet in 1954. In spite of this situation, it appears that the ground water resources can continue to support a gradually expanding agriculture and the growing urban communities for many years to come. Professor Snyder has estimated an average overdraft of 185,000 acre-feet in the 1970's, which would mean pumping from about 350 feet in 1975.[2]

The ground water which supports the present irrigation economy is available to farmers at low cost. With present pumping lifts and power rates, this water is produced in Antelope Valley at an average cost of about $10 per acre-foot, including amortization of the investment in wells. It appears that this is approaching the maximum that farmers can afford to pay for water in this area. The rate of new investment in wells to expand irrigated acreage in Antelope Valley has declined considerably in recent years as pumping lifts and resulting water costs have increased.

For the present study, estimates of net farm income before the payment of water costs were made, to indicate the maximum amount farmers would have left from crop income to pay for water in the future. In these estimates an allowance was made for more efficient use of water, labor, and equipment in the future than is typical of the area at present. Allowance was also made for a shift in the cropping pattern to crops requiring less water. If these improvements in water utilization are made, the average cost of locally produced water would remain about the same per acre of crops as in 1955, in spite of higher per acre-foot cost of water encountered as pumping lifts increase, until a lift of about 350 feet is reached. Long-term average prices were used in estimating other production costs and crop income.

It is estimated that in 1976—the scheduled date for delivery of Feather River Project water—the average water requirements per acre, weighted on the basis of the anticipated cropping pattern, will be about 3.40 acre-feet. The corresponding average net farm income before water cost is estimated as $53 per irrigated acre, or $15.60 per acre-foot of water required.

The net farm income shown above is before any return to the farmer in his capacity as manager of the farm enterprise, only a return for his labor having been treated as a cost. Thus, the entire amounts shown probably cannot be considered as available to pay water cost. The general magnitudes, however, are significant for the Feather River Project. It can readily be seen that, after allowing several dollars per acre-foot which would be required for local water distribution costs, the price which farmers could afford at the aqueduct is probably less than $10 per acre-foot.

The farmer's ability to pay for water was analyzed by Professor Snyder by somewhat different methods. His findings are comparable to those obtained here.[3]

There are several reasons for the low average net farm income before water costs. The area lies at an elevation of about 2,500 feet and is subject to extreme temperature variations. The growing season is short, averaging only 210 days per year. Such a climate is not suitable for the high value crops, such as citrus, grown in other parts of Southern California. The short season handicaps the area in the production of truck crops in competition with the Imperial Valley and other areas in California.

[1] Herbert J. Snyder, *The Experience of Antelope Valley*, Ground Water Studies No. 2, University of California, Berkeley, February, 1955.
[2] *Ibid.*, p. 95.
[3] *Ibid.*, p. 116.

Water agencies are frequently supported by both water revenues and taxes. When such situations occur in areas with both urban communities and irrigated land, it is sometimes possible for the urban area of high assessed valuation to produce enough tax revenue for the agency to allow irrigation water to be sold at relatively low prices in spite of high total costs in providing the water. No agency of this sort exists in the Antelope Valley-Mohave Desert Area, and the limited extent of the urban communities makes it appear unlikely that arrangements providing large quantities of water for agriculture in this manner will be made. It is therefore concluded that there would be no market in this area, at prices which would cover the average cost of providing the water, for the large quantities indicated in the Feather River Project report. Some demand for urban use will probably develop, but the availability of ground water supplies which could be exploited for some time to come makes the date at which such demand will become effective quite uncertain.

South Coastal Area. This possible service area extends from the western boundary of Ventura County to the Mexican border. It includes the heavily populated portions of six counties—Ventura, Los Angeles, Orange, Riverside, San Bernardino, and San Diego. It is estimated that in 1950 about 98 percent of the population of these six counties lived in the South Coastal Area.

The rapid population growth in this part of California during the present century is well known. The Los Angeles metropolitan area is expected to surpass that of Chicago by 1960 and become the second largest population center in the Nation.

As the population has increased, thousands of acres of irrigated land have been shifted to urban uses. Since the principal remaining irrigated lands are immediately adjacent to rapidly expanding cities, this process is expected to continue apace. At the same time, however, there are lands more distant from the present cities which appear to be suitable for irrigation and which either do not now have water or have only recently acquired access to a water supply. Some new irrigation through development of these lands is probable. There are thus two aspects to the future demand for water in the South Coastal Area—the requirements of the growing cities and the possible development of new irrigated lands.

Demand for Irrigation Water. The development of new irrigation will be sensitive to the price at which water is made available to farmers, and it will depend also on all those other economic factors which affect the profitability of growing the crops adapted to the area. The extreme diversity of the South Coastal Area in soils, topography, and climate further complicates the evaluation of irrigation potential. Because of the complexity of the analysis which would be required to project the demand for irrigation water in this area, it was not possible to undertake any study of this problem in the time available for this report.

This does not mean that future irrigation demand is unimportant in the South Coastal Area. On the contrary, it would have an important bearing on the date on which Feather River Project water will be needed and the quantities which can be sold.

Some large rural areas have recently become part of the Metropolitan Water District of Southern California. Present price policy of the Metropolitan Water District makes water available to these areas at a rather low price. To the extent that such lands become irrigated and draw on the available supply of Colorado River water, the amount of Colorado River water left to meet the growing requirements of the cities will be reduced, and the date at which Feather River Project water will be needed will be correspondingly advanced.

It is recommended that the prospects for new irrigation in the South Coastal Area be studied in detail. This is important with respect to the timing of Feather River Project water delivery in the area and with respect to the quantities of project water which might be used for irrigation. The policies of the Metropolitan Water District concerning water price and concerning the rate at which aqueduct capacity to deliver Colorado River water will be increased will have an important bearing on the problem of timing. The costs of distributing Feather River Project water in the area and the organization and price policies of the water agencies serving farmers with project water should be examined in relation to the price which farmers could afford to pay for water to irrigate new lands. This will be necessary to determine whether project water can be purchased by farmers under arrangements which will yield an appropriate return to the Feather River Project.

The organization through which Feather River Project water can be distributed and the costs of local distribution will be particularly important in determining the potential demand for project water in Ventura County. Without detailed study of these matters, in connection with the ability of farmers to pay, it is not possible to determine whether appreciable quantities of project water could be sold in Ventura County at a price providing an appropriate return. This matter should also be investigated further, since a market for 75,000 to 100,000 acre-feet of water is involved, and this market could be particularly important in the early years of delivery to Southern California.

Urban Water Requirements. The urban communities in the South Coastal Area could readily afford to pay the cost of providing Feather River Project water to the area. In view of average total costs of supplemental water which have been paid by commu-

nities in this area in the past, it appears clear that the anticipated cost of providing Feather River Project water would not tend to restrict water use. Projections of the future growth of population in the area were therefore made, and estimates of the demand for project water were made, based on the population growth figures.

The population growth estimates used for the South Coastal Area are based on projections made for California in *Population Trends in the United States Through 1975*, by Howard C. Nielson.[1] These trends were extended to provide estimates for later years, and the growth of the area was estimated in relation to that projected for the State. These estimates are based on the assumptions that birth rates will decline gradually after 1960, that death rates will continue their decline but at a less rapid rate than in the past, and that net migration to California will average 315,000 annually.

In the study of population growth, the extended metropolitan area of Los Angeles lying in Los Angeles, Orange, Riverside, and San Bernardino Counties was considered as a unit. Even though parts of the metropolitan area may become completely occupied in the rather near future, the attraction of the entire area for new population was assumed to continue, with correspondingly higher growth rates in the parts where land is available. If the recent growth tendencies observed in California and in this metropolitan area continue in the future, the combined population of the parts of these four counties within the South Coastal Area would increase from 4,713,000 in 1950 to 11,456,000 in 1975. If these tendencies continue to the end of the century, the total would rise to about 20,000,000.

Similarly, if recent growth tendencies continue, the San Diego County portion of the area would increase from a population of 553,000 in 1950 to 1,728,000 in 1975 and attain a total of about 3,000,00 at the end of the century.

Ventura County was not included in the estimate of urban water requirements. Local water conservation projects being planned in that county appear adequate to meet the needs of the principal cities for quite a long period. Delivery of water to the smaller communities in the water-deficient area of the county would appear to depend on arrangements which would simultaneously supply irrigation water to the area. As mentioned earlier, the entire problem of deliveries to Ventura County requires further study.

As the population becomes very large in the metropolitan areas and as more and more distant years are considered, the uncertainties involved in population projections necessarily increase. To ascertain the effects of growth at a slower rate than that indicated by recent tendencies, water requirements were also estimated on the basis of future growth 20 percent less than that indicated in the foregoing paragraphs.

Many factors other than gross population in the area will affect the demand for project water. Since the initial water delivery is scheduled 20 years in the future, there are necessarily uncertainties with respect to these factors also. The principal factors and the assumptions made with respect to them are discussed in the following paragraphs:

An important consideration, of course, is the average quantity of water required per person living and working in the area. In the past there has been a tendency for per capita requirements to increase. For the future there appear to be tendencies which would continue this increase, but at the same time tendencies which would reduce the water requirements. The use of home appliances, air conditioning, and other water-using devices will probably continue to increase. However, there appear to be opportunities for additional conservation of water in industrial uses, and more intensive land utilization may reduce requirements for lawns and gardens. For purposes of the water demand estimates, it was assumed that average per capita water use would continue to increase, being about 10 percent higher in 1975 than in 1950.

When urban communities occupy irrigated land, the water formerly consumed in irrigation is released for other uses. In the South Coastal Area such water would become available for urban use, and it was necessary to make allowances for this in estimating the net increase in water requirements resulting from population growth. Estimates were made of the land area expected to be occupied by the projected population at five-year intervals, thus indicating the irrigated acreage converted to urban use. The water thus made available was computed, using the per acre consumptive requirements of irrigated land in the area in 1950 as shown in State Water Resources Board Bulletin No. 2, *Water Utilization and Requirements of California.*

Another factor of some importance in determining future water needs is the extent to which the urban area is served by sewers draining to the ocean. In substantial parts of the South Coastal Area, water which penetrates beyond the root zone of plants ultimately joins a ground water supply from which it can be recovered. When waste water is discharged in such ground water areas through septic tanks or through sewage treatment plants not connected to an ocean outfall, the net urban consumption in terms of water lost to the area is considerably less than when all wastes are discharged to the ocean. It is difficult to predict the times at which areas not presently sewered to the ocean will install such sewers.

Estimates of water requirements through 1985 were made, both on the basis of the entire area being sewered to the ocean and on the assumption that there

[1] Stanford Research Institute, August, 1955.

is recovery of return flows in the inland areas. This was done to show the effect of this factor on the potential demand for project water.

In showing the potential urban demand for Feather River Project water, it was assumed that the project would meet all requirements above those which can be met by local ground water and surface supplies, as augmented by presently established sources of imported water. No allowance was made for reclamation of sewage, conversion of sea water, or other artificial sources. It was assumed that the entire amount of the right claimed by the Metropolitan Water District in the Colorado River will be available. This right is 1,212,000 acre-feet annually, of which a small amount must be allowed for conveyance losses en route to South Coastal Area users. A large portion of this entitlement is not being utilized at present.

One of the most important factors affecting demand for project water is the extent to which local ground water sources are drawn upon in excess of their average safe sustained yield. State Water Resources Board Bulletin No. 2 shows an overdraft in the South Coastal Area, excluding Ventura County, of 323,000 acre-feet in 1950. The annual overdraft is believed to have increased substantially since that time. Most of this occurs in the Los Angeles metropolitan area. Obviously, this overdraft cannot continue indefinitely. However, the underground basins are very large, and a substantial overdraft can probably be sustained for a rather long time. Hydrographic engineers with whom this matter was discussed were unwilling to predict probable future developments with respect to this overdraft.

Organized efforts are now being made in some places to curtail the overdraft on ground water through control of pumping and through replenishment of the basins with Colorado River water. On the other hand, it is cheaper to pump from wells than to purchase imported water, thus affording an economic incentive to the fullest possible utilization of ground water. To allow for the uncertainties in this situation, the demand for Feather River Project water was estimated on the assumption that the overdraft would be eliminated, and also on the assumption that overdraft will continue at the 1950 rate.

The demand for project water for urban use in the South Coastal Area, as estimated under the several possible sets of conditions just described, is shown in Table X. In each case, however, it is assumed that the entire supply available from the Colorado River would be used before any Feather River Project water is used.

It can be seen that a substantial urban demand could develop by 1970 if the population continues its recent rapid growth, if the overdraft on ground water is eliminated, and if the area is completely sewered to the ocean. On the other hand, the development of a substantial demand could conceivably be postponed to 1985 if there is a marked reduction in the population growth rate, if a heavy overdraft on the ground water can be continued for 30 years, and if the inland areas are not sewered to the ocean.

TABLE X

ESTIMATED URBAN DEMAND FOR FEATHER RIVER PROJECT WATER

SOUTH COASTAL AREA, 1960-2000

(Acre-feet)

Year	Entire area sewered to ocean		Riverside-San Bernardino areas[1] not sewered to ocean	
	1950 overdraft continued	Overdraft eliminated	1950 overdraft continued	Overdraft eliminated
With continuation of recent population growth tendencies				
1960	--	--	--	--
1965	--	--	--	--
1970	--	226,000	--	126,000
1975	183,000	506,000	73,000	396,000
1980	495,000	818,000	283,000	606,000
1985	828,000	1,151,000	563,000	886,000
1990	1,182,000	1,505,000		
1995	1,569,000	1,892,000		
2000	2,026,000	2,349,000		
With population growth 20 percent less than above				
1960	--	--	--	--
1965	--	--	--	--
1970	--	--	--	--
1975	--	279,000	--	191,000
1980	196,000	519,000	26,000	349,000
1985	462,000	785,000	250,000	573,000
1990	746,000	1,069,000		
1995	1,055,000	1,378,000		
2000	1,421,000	1,744,000		

[1] This area might not be sewered to the ocean for some time. However, the population would be large by 1990, and eventual sewering seems likely.

In view of the rather long period before this demand can be expected to materialize and with the possible range of variation in timing, it would be desirable to retain as much flexibility as possible in project plans to serve this area. However, even without any allowance for new irrigation, it can be seen that the South Coastal Area could probably use, by the end of the century, all the water scheduled in the project for delivery to Southern California. For preliminary planning purposes, the schedule shown in the Feather River Project report appears reasonable. The area should be kept under study so that plans can be adapted to needs as they become more clearly defined in the future.

Present Water Costs in South Coastal Area. More than a thousand water service agencies are operating in Southern California. In many cases one agency supplies other agencies with water, so that several may be involved between the water source and the

ultimate water user. These agencies are supported by a variety of water sales revenues, taxes, and assessments. Many agencies secure water from more than one source at different costs. It is therefore not possible to indicate in any simple manner the present cost of water to this large and diverse area.

Present water costs are of interest in connection with the Feather River Project principally in relation to the water revenues required in the service areas of that project for each service area to pay its pro-rata share of project costs. Retail sales of water to ultimate users are not contemplated from the Feather River Project. Rather, the water would be sold to distributing agencies, and the water revenues discussed in the Feather River Project report are based on such distributors taking delivery of the water at the main aqueduct. Project water revenues would be only a part of the cost of water to the consumer, because the costs of distribution within the service area must be added.

The costs of local distribution will vary greatly from place to place, depending on distance, terrain, type of distribution facilities, location of the Feather River Project aqueduct, etc. It was not possible in the scope of this study to evaluate local distribution costs in parts of the South Coastal Area to estimate the price at which Feather River Project water might be delivered to ultimate users.

The possible delivered price of Feather River Project water is further complicated by the probable mixture of this water with water from other sources. The most efficient distribution of project water would be achieved by utilizing existing facilities and agencies to a very large extent. These agencies are presently delivering water obtained at a variety of costs from local wells, reservoirs, and imported supplies. A growing proportion of Colorado River water obtained through the Metropolitan Water District of Southern California is being used. As the water "mix" in an area changes over time and as the capital cost of facilities is either paid off or spread over changing quantities of water, the average cost of water per acre-foot will also change. Only a detailed study of each locality could provide an estimate of the average cost of the prevailing supply which might be expected at the time Feather River Project water becomes available.

The institutional arrangements under which water is obtained and financed have very important implications for the significance of water cost as a factor affecting water use. If a water supply is developed by a public agency, a large part of the total cost may be paid in taxes, with a correspondingly small part of the cost covered by the water sales revenues. This is a common situation, of which a major example is the Metropolitan Water District of Southern California.

The current water prices charged by the Metropolitan Water District to its member agencies are much less than the costs incurred by the district in supplying the water. The difference is made up in taxes on property in the district. Such a situation encourages water use, since the tax cannot be avoided by not using water, and only the relatively low selling price becomes a factor in the purchaser's decision to buy water. Some areas which have substantial irrigable lands have recently become part of the Metropolitan Water District, and this price policy will probably make possible the purchase of irrigation water in places in which charging the full cost of providing the water would make irrigation uneconomic.

When a water supply is supported partly or wholly by taxes and the water agency includes urban areas with high assessed valuation, it becomes possible to develop supplies for which the total cost per acre-foot is high. At the same time, these supplies can be made available to users, as described above, at prices which are economic to them as individual purchasers of water. The impact of Feather River Project water price on the quantity of that water which will be used obviously depends on the nature and policy of the distributing agencies which buy the project water at the aqueduct.

In the paragraphs which follow, some examples of current water prices and costs in the South Coastal Area are presented. Because of problems encountered in reducing all figures to a comparable basis, no attempt has been made to show the data in tabular form.

In August, 1955, the San Diego County Water Authority completed a study of water costs in the various agencies included in the territory of the authority. Water prices paid by consumers for domestic use (assuming 1,000 cubic feet per month and a $\frac{3}{4}$-inch meter) ranged from $82.76 to $226.50 per acre-foot. Consumer prices for irrigation water (assuming 25,000 cubic feet per month and a $1\frac{1}{2}$-inch meter) ranged from $16.17 to $96.35 per acre-foot. These prices represent the charges appearing on consumers' water bills. In addition, taxpayers in the various agencies contributed amounts which varied among the agencies from $3.63 to $56.38 per acre-foot. When the total cost of the water is considered, including both sales price and taxes, the range for domestic use is from $122.10 to $226.50, while that for irrigation water is from $42.13 to $104.21. The taxes mentioned here include the levies of the Metropolitan Water District, the San Diego County Water Authority, and the local distributing agency as applicable to the water delivered in each local area.

The Metropolitan Water District of Southern California sells water to its member agencies for $10 per acre-foot unsoftened and $20 per acre-foot softened. All water delivered west of the district treatment plant at La Verne is softened. That supplied to the San Diego County Water Authority is unsoftened. In addition to these charges, the district levies a tax on all property in the district. The tax rate has been

declining over the past ten years as assessed valuation and water revenues have increased. The rate in the fiscal year ending June 30, 1954 was $0.25 per $100 of assessed valuation. The various member agencies are not using Colorado River water in proportion to their assessed valuations, which means that the tax payment per acre-foot of Colorado River water used varies widely from one member agency to another.

In the fiscal year ending June 30, 1954, the Metropolitan Water District had total costs for operations, interest, and bond redemption in excess of $15,000,000, while water sales revenues were $3,648,164. Thus, the selling prices mentioned above covered less than 20 percent of the total cost in that year.

In the Orange County Water District, which covers an important part of Orange County, water is pumped locally from wells with a considerable range of depths. The average cost for pumping and well amortization is estimated to be $6.50 per acre-foot. To this must be added a tax of $3.50 per acre-foot, which is levied for the purpose of buying Colorado River water for percolation to replenish the ground water in this area. Property in this area is subject to Metropolitan Water District taxes. Local water agency taxes are nominal.

The Western Municipal Water District of Riverside County covers a large area in the vicinity of Riverside and Corona. Distributing organizations in this district are delivering irrigation water at prices ranging from $17 to $20 per acre-foot, with some small quantities being priced as high as $24 per acre-foot. Metropolitan Water District, Western Municipal Water District, and local improvement district taxes are in addition to these water prices. Data which would indicate total costs including taxes were not readily available.

The Eastern Municipal Water District serves the San Jacinto River basin in Riverside County. Charges to consumers in this area run from $17.50 to $22.50 per acre-foot. Taxes levied for 1955-56 amount to $1.36 per $100 of assessed valuation for Metropolitan Water District and Eastern Municipal Water District charges. Improvement district levies amount to an additional $1.00 per $100 of assessed valuation for bond retirement.

Data were secured on the cost of producing water from wells for the city supply in Los Angeles, Long Beach, Pasadena, Santa Monica, and Burbank. These costs range approximately from $4.00 per acre-foot to $12.00, depending on pumping depth and treatment required. It is thus advantageous for these cities to use local ground water when possible rather than to purchase softened water from the Metropolitan Water District at $20 per acre-foot. These cities are all in the Metropolitan Water District and subject to its taxes.

Alameda-Santa Clara-San Benito Counties Service Area

This area of mixed urban and agricultural development could be supplied with water early in the Feather River Project, but it would account for a relatively small part of total water deliveries at all stages of the project. The Feather River Project report shows 60,000 acre-feet needed for this area in 1964, increasing to 240,000 acre-feet in 1979. The average water sales revenue which would be required for the area to pay the costs of service would be from $17.50 to $22.50 per acre-foot, depending on what facilities are included in the project.

For analysis of irrigation water requirements, this area is similar to the South Coastal Area. Future irrigation developments will be sensitive to the price at which water is made available to farmers; and the diversity of conditions in the service area makes it impossible to make a detailed analysis of potential irrigation requirements within the time available.

It is probable that some demand for irrigation water would develop in southern Alameda County and in northern San Benito County. Opportunities for new irrigation in the northern portion of Santa Clara County appear to be quite limited. A recent study by the Division of Water Resources[1] indicates that the southern portion of this county, approximately from Morgan Hill to the county line, can economically meet all its foreseeable water requirements through local conservation measures.

A principal source of demand for Feather River Project water in this service area will be the rapidly expanding urban communities in southern Alameda County and northern Santa Clara County, where the cost of the water will not restrict use. Estimates of the future growth of urban water requirements in these counties are described in the following paragraphs.

Study of this service area led to the conclusion that the area as outlined in the Feather River Project report includes some important communities which are not likely to be served by the project. For example, the rapidly growing city of Hayward, in southern Alameda county, has been purchasing increasing quantities of water from the San Francisco Water Department in recent years. The growth of this community will require substantial additional quantities before service from the Feather River Project could begin. The Division of Water Resources recently assumed that Hayward and all the area lying north of the northern boundary of the Alameda County Water District will be served by the San Francisco Water Department and the East Bay

[1] Santa Clara Valley investigation. See "Present and Ultimate Seasonal Supplemental Water Requirements in Alameda, Santa Clara, and San Benito Counties," one page, mimeographed, dated September 29, 1955. Submitted by Division of Water Resources at hearings held by Joint Committee on Water Problems, Legislature of the State of California, in San Jose, October 5-6, 1955.

Municipal Utility District.[1] A map recently released by the East Bay Municipal Utility District shows that the area in question is within the ultimate boundaries expected for that district and justifies this assumption by the Division of Water Resources. The area north of the Alameda County Water District was therefore excluded in making the demand estimates in this study for Feather River Project water.

Palo Alto, in northwestern Santa Clara County, was also excluded from the area covered in the demand estimates. Palo Alto presently purchases supplemental water from the San Francisco Water Department, which appears to have an adequate supply to meet the future needs of the city. It appears that considerable difficulty would be encountered in delivering Feather River Project water to Palo Alto, because it lies at a considerable distance from the proposed route of the aqueduct. If the water were delivered in the raw state, treatment facilities not now required in the city would be necessary to prepare the water for use. The city is not included in the Santa Clara Valley Water Conservation District and so does not participate in the ground water replenishment activities of that district.

To estimate the growing water requirements of urban communities in the relevant parts of the service area, population projections were made for Alameda and Santa Clara Counties, assuming continuation of past growth tendencies in these counties and in California as described earlier with respect to the South Coastal Area.

The areas which would be occupied by the projected population at intervals in the future were estimated on the basis of land availability and typical population density patterns. Allowance for the displacement of irrigated agriculture was made, and the net increase in water requirements resulting from urban growth was calculated on the basis of per capita water use.

For these estimates, it was assumed that there would be no recovery of sewage and waste water from the urban areas. Some unsewered communities are developing and will continue to do so over free ground water basins. While these communities will probably be sewered to San Francisco Bay eventually, the time when this will occur cannot be accurately predicted. In the early part of the project period, some recovery of water from these communities may occur, which would make the requirements somewhat lower than those shown here.

In the Alameda County portion of the service area, an average population density of 10 persons per acre of gross urban development was assumed, with an average water requirement of 140 gallons per capita per day. State Water Resources Board Bulletin No. 13 contains estimates of water requirements for the year 2000, based on a density of 8.0 persons per acre in the Livermore Valley and 9.1 persons per acre in the coastal portion of southern Alameda County. The per capita water requirements used in the bulletin are 139 and 133 gallons per day, respectively, for these subareas.[1] The higher population density assumed for the present study implies a slower encroachment on the presently irrigated lands and consequently less water released from agriculture for urban use in the early years than do the figures used in Bulletin No. 13. This, in addition to the slightly higher per capita requirements used here, makes the present estimate on a somewhat more liberal basis than that in Bulletin No. 13. The population growth estimates used here are considerably higher than those used in the bulletin.

In northern Santa Clara County, an average urban population density of 10 persons per acre was also assumed. Water requirements were based on 160 gallons per capita per day. Reports obtained from the larger water service agencies in this area indicate a wide variation in current use, but all reports were considerably less than 160 gallons per capita per day.

Data on urban land use and water use per acre developed in the recent Santa Clara Valley investigation of the Division of Water Resources show a requirement of 1.8 acre-feet per acre in the ground water pressure zone. With ten persons per acre, this would mean about 160 gallons per capita per day. This estimate is said to be based on data obtained in the Raymond Basin adjudication in Los Angeles County, with adjustments for Santa Clara County conditions. The estimates of present use contained in State Water Resources Board Bulletin No. 2 cannot be reconciled with either the Santa Clara Valley investigation or reports of local water agencies. However, it is believed that an average allowance of 160 gallons per person per day is quite adequate.

In this connection, it is of interest to note that the East Bay Municipal Utility District had an average daily gross water consumption in 1954 of 119 gallons per person in its service area. For the fiscal year ending June 30, 1954, the San Francisco Water Department reported an average total daily consumption in the City and County of San Francisco, which (for the estimated population in that year) would be 114 gallons per person. Average daily per capita use in Palo Alto since 1950 has ranged from 142 to 152 gallons. In Sunnyvale, average daily per capita use in the fiscal year ending June 30, 1955, is estimated at 132 gallons. In San Jose and Santa Clara, the water agencies report about 100 gallons per capita per day as average consumption.

The differences among these figures, particularly those among the Santa Clara County communities, cannot be readily explained. However, it appears that

[1] State Water Resources Board Bulletin No. 13, *Alameda County Investigation*, July, 1955, pp. 3-44.

[1] *Ibid.*, pp. 3-38.

TABLE XI

ESTIMATED URBAN DEMAND FOR FEATHER RIVER PROJECT WATER

ALAMEDA, SANTA CLARA, SAN BENITO COUNTIES, 1960-2000 [1]

(Acre-feet)

Year	Alameda[2]	Santa Clara	San Benito	Total[2]
1960	29,500	6,300	200	36,000
1965	35,600	11,300	400	47,300
1970	41,900	17,700	600	60,200
1975	48,600	25,000	800	74,400
1980	55,300	33,400	1,100	89,800
1985	64,800	43,000	1,400	109,200
1990	84,700	57,100	1,700	143,500
1995	105,300	73,500	2,000	180,800
2000	126,000	91,200	2,400	219,600

[1] Assumes no overdraft on local ground water sources in Alameda and Santa Clara Counties.
[2] Construction of Sanatorium Dam would reduce these amounts 13,200 acre-feet.

liberal assumptions have been made with respect to future use in both Alameda and Santa Clara Counties.

The principal town in the San Benito County portion of the service area is Hollister. There is little basis on which to estimate future growth in a small community of this sort, which is not immediately adjacent to a metropolitan area. Single events which cannot be foreseen can have a very strong impact on a small town. For example, one medium-sized industrial plant moving into the community could cause it to double in population. The annual water requirement of Hollister was recently estimated as 800 acre-feet.[1] An additional 800 acre-feet has been assumed to be required by 1975, increasing to 2,400 acre-feet of new demand by the year 2000. While the uncertainty surrounding these figures is great, the magnitudes are so small in relation to the Feather River Project that no great effect on total demand in the service area is involved.

The estimated demand for Feather River Project water resulting from urban growth in the Alameda-Santa Clara-San Benito service area is shown in Table XI. In deriving these figures, it was assumed that use of local ground water supplies would be limited to the average safe sustained yield. The timing of purchases of project water could be influenced by a sequence of wet or dry years preceding completion of the project, which might affect the willingness of water purchasing agencies to allow overdrafts to occur.

State Water Resources Board Bulletin No. 13 discusses the possibility of conserving an annual average of 13,200 acre-feet of local surface runoff in Alameda County through construction of a dam and reservoir in Arroyo del Valle at the Sanatorium site. The estimated cost per acre-foot of the water so conserved is $16. These figures are based on using the reservoir in conjunction with underground storage which would be replenished by reservoir releases. No agency is known to be contemplating construction of Sanatorium Dam at this time. However, the indicated cost of water from this source is somewhat less than the average cost of bringing Feather River Project water to the Alameda-Santa Clara-San Benito Counties service area. If the dam were built, the demand for project water shown in Table XI would be reduced accordingly.

The demand for project water in the table is less than the 60,000 acre-feet shown in the Feather River Project report for delivery in 1964, and it is substantially less in 1980 than the full 240,000 acre-feet shown as reached in 1979. The figures in the table are for urban demand alone, of course, and any demand arising from the development of new irrigated land would be in addition. Although a quantitative analysis of irrigation demand was not possible here, some demand for this purpose should be expected.

There is also a present annual overdraft of several thousand acre-feet in the area now irrigated in San Benito County. No allowance for overcoming this situation has been included.

Even with some demand for irrigation in addition to the urban requirements shown in Table XI, it appears that the rate of growth in deliveries to this area would be slower than that shown in the Feather River Project report. However, before the end of the century, the entire amount allotted to this area from the project will probably be required.

Present water costs in this service area are of some interest in connection with project planning. Ground water is the chief source of supply, and the pumping lift varies greatly from place to place. The costs of pumping ground water appear to range from about $8 to $15 per acre-foot. The Santa Clara Valley Water Conservation District has facilities for replenishing ground water with surface runoff at an average rate of 91,000 acre-feet per year. The district estimates the average cost of salvaging this water to be $5.19 per acre-foot. These operations are supported by taxes. The San Francisco Water Department furnishes supplemental water to urban communities in this area at rates averaging about $70 per acre-foot.

Feather River Service Area

This area lies along the Feather River between Oroville Dam and the Sacramento-San Joaquin Delta, extending from the city of Oroville downstream to the junction of the Feather and Sacramento Rivers. Most of the area lies west of the Feather River, since the floor of the Central Valley generally slopes in that direction, making it possible to take water from the river by gravity. Butte Creek, tributary to the Sacramento River, and Sutter By-pass generally mark the western boundary. The area contains over 400,000 acres and includes the lands presently utilizing water from this part of the Feather River.

[1] U. S. Bureau of Reclamation, *Reconnaissance Report, Hollister Project, Pajaro River Basin, California*, January, 1954, p. 33.

Although it is not served by the project aqueduct, it is necessary to consider water use in this area in project planning. The control of the river by Oroville Dam would make it possible for diverters in the area to capture more water for beneficial use than they now secure from the unregulated stream. Thus, allowance for diversion must be made in calculating the water which will be available in the Delta for pumping in to the aqueduct.

In this connection, it is necessary to be concerned only with the net consumptive use of water in the area. Water applied in irrigation in excess of consumption requirements returns to the Feather-Sacramento River drainage system and eventually reaches the Delta. The same is true of water utilized in nonconsumptive uses in urban communities.

The Feather River Project report shows diversion from the river in 1952 as about 730,000 acre-feet, of which some 400,000 acre-feet were consumptively used. In a dry year the possible diversion is limited to about 410,000 acre-feet. Under project conditions, a firm supply of 730,000 acre-feet would be made available each year. In estimating availability of water in the Delta, an allowance was made for increasing the diversion to 970,000 acre-feet and the consumptive use to 721,000 acre-feet as the area achieves its ultimate state of development.

Most of the water now used in this area is diverted from the Feather River onto irrigated lands. Urban uses are relatively minor. About 90 percent of the total diversion in 1954 was accounted for by the Western Canal Company and the Sutter Butte Canal Company. The latter is the larger of these and supplies water to the Biggs-West Gridley Water District, Richvale Irrigation District, and Sutter Extension Water District, in addition to serving water users on its own account. It is through these organizations that water is diverted to those parts of the area remote from the river. Secondary users are able to utilize some of the water which drains from irrigated land, particularly rice fields, to which it was first applied. A number of small diversions are accomplished by pumping on both the east and west banks of the Feather River.

Some ground water is pumped throughout the area, but the most extensive pumping occurs in the so-called Peach Bowl, where there is presently an overdraft on the ground water. In making the estimates used in the Feather River Project report, it was assumed that there would be sufficient use of river water to offset the overdraft and allow ground water to be used on a safe sustained yield basis.

The Feather River Project report indicates that approximately 146,000 acres were irrigated in this area in 1952. The allowance for future water use is based on 272,000 irrigated acres. The extent of irrigable land was determined according to the criteria used in State Water Resources Board Bulletin No. 2. A map from this bulletin was compared with a United States Bureau of Reclamation land classification map of the area and the two were found to be very similar.

In general, the criteria used by the Bureau of Reclamation define irrigable land more narrowly than the criteria used for Bulletin No. 2. However, the land in this region is relatively homogeneous over large areas, and much of it falls within the standards set by both organizations, with little left in the borderline categories. Most of the nonirrigable land consists of the Sutter Buttes, swamplands along Butte Slough, rough land in the northeast corner of the service area, and tailings near the main stream.

The major part of this service area is composed of the territory designated in State Water Resources Board Bulletin No. 2 as hydrographic units 24 and 25 of the Central Valley Area. The remainder is made up of parts of hydrographic units 26 and 30. The figures used in the Feather River Project report for presently irrigated and potentially irrigable acreage appears to include only units 24 and 25. However, the figures used in the report for present and future consumptive use of water cannot be reconciled exactly with the corresponding Bulletin No. 2 figures for units 24 and 25. It appears that in the allowance for future consumptive use shown in the report, an additional quantity has been included to cover the portion of the service area east of the river in units 26 and 30. This would, of course, be entirely proper.

It is also proper in analyzing this service area to use the Bulletin No. 2 concept of ultimate water requirements, since an allowance should be made for all the water which might be required ultimately in this area through which the stream must flow before reaching the aqueduct intake in the Sacramento-San Joaquin Delta.

The consumptive use requirements of the various crops grown in this area—as developed for Bulletin No. 2—were checked against other estimates and the experience of similar areas, and it was concluded that appropriate values are used. The cropping pattern estimated for the area in the future was also believed to be quite reasonable.

For Bulletin No. 2, the ultimate consumptive use of water in urban areas in the Central Valley is based on the assumption that population density will increase to 15 persons per acre. In view of current trends in land use in the State, it appears improbable that density will be this great. The urban area might therefore be larger than that shown in the bulletin. However, this would have little or no effect on the total water requirement of the area, since expansion of the urban area would reduce the irrigated acreage, and the unit requirements are about the same in both types of land use. In any case, the urban requirements in this service area are of minor importance to the total quantities of water being considered here.

All factors considered, the estimates of ultimate consumptive use of water applied to this area as shown in Bulletin No. 2 are believed to be quite acceptable. Since hydrographic units 24 and 25 account for nearly all of the service area, this provides a ready check on the allowance made in the Feather River Project report for water to be used in the area. The ultimate consumptive use of applied water shown for these two units is 684,500 acre-feet. When some allowance is also made for the small portion of the service area which is outside these two units, the total allowance of 721,000 acre-feet in the Feather River Project report appears adequate for ultimate development of the area.

No revenues have been shown in the report for water which the project would make available to this area. From the standpoint of charging for this water, a question arises as to the extent to which the Feather River supply to this area is already owned by present and potential users, making it immune to diversion charges.

Areas along the Sacramento River have been affected by the regulation of that stream at Shasta Dam in much the same manner that this service area would be affected by Oroville Dam. Complex problems of water rights have arisen in this connection, and a substantial effort is currently being made to reach satisfactory arrangements concerning diversions from the Sacramento.

The Feather River service area has a long history of water appropriation from the river. In addition to rights of appropriation, riparian rights exist along both sides of the stream. Riparian rights, which are held by all lands contiguous to the river, are paramount and take precedence over appropriative rights, whether or not exercised.

Nearly all the diversions east of the river are of the riparian type. The principal diversions west of the river are appropriative and supply areas remote from the stream. It appears that a large part of the service area has water rights of one kind or the other, with some overlapping.

The price of diverted water at the riverside is now zero. The Richvale, Sutter Extension, and Biggs-West Gridley districts are currently delivering water to farmers' head gates at costs equivalent to $2 to $3.50 per acre-foot, including revenue bond charges. These low costs of presently used water may create pressure to keep water costs low in the area.

The State Division of Water Resources is aware of all these problems and is studying the possibility of deriving some revenue for the project from the water made available to this area.

APPENDIX B

REPORT

BLYTH & CO., INC. STONE & YOUNGBERG HELLER, BRUCE & CO.

FEASIBILITY OF FINANCING
THE
FEATHER RIVER PROJECT

FEASIBILITY OF FINANCING THE FEATHER RIVER PROJECT

Prepared for

BECHTEL CORPORATION
SAN FRANCISCO, CALIFORNIA

by

BLYTH & CO., INC. STONE & YOUNGBERG HELLER, BRUCE & CO.

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December 19, 1955

BECHTEL CORPORATION
220 Bush Street
San Francisco 4, California

Attention Mr. J. R. Kiely, Vice President

GENTLEMEN: In accordance with your instructions we submit hereunder our report and recommendations relating to the feasibility of financing the proposed Feather River Project.

INTRODUCTION

It is our understanding that Bechtel Corporation was selected by the Joint Committee on Water Problems of the State Legislature to make an independent review of the report entitled "Program for Financing and Constructing the Feather River Project as an Initial Unit of the California Water Plan," submitted by the State Engineer earlier this year. In connection with this review you have selected us to make certain studies and submit recommendations relative to financial aspects of three separate plans of project construction.

The three plans under consideration hereinafter referred to as "Route 1," "Route 8A" and "Route 10A" are described briefly as follows:

Route 1—The State's proposed High Line route to Barrett Reservoir.

Route 8A—Bechtel's proposed High Line route to Devils Den and coastal route to terminal point in Granada Hills Reservoir.

Route 10A—Bechtel's proposed High Line route to Quail Lake terminating at Granada Hills Reservoir.

Data and information used in making the calculations shown in this report were obtained from several sources, including specifically the following:

All estimated construction costs and construction time schedules and all estimated project revenues and annual costs exclusive of bond service, applicable to each of the three plans, were obtained from Bechtel Corporation.

Estimates of population growth in California to the year 2000 were obtained from Stanford Research Institute.

Data and information relating to the State's fiscal operations were obtained from the office of the State Treasurer and from various publications and reports.

PURPOSE OF REPORT

The principal purposes of this report are as follows:

(a) To discuss generally the two types of bonds that might be used to finance the capital costs of the project and to make appropriate recommendations with respect thereto.

(b) To estimate the average interest rate at which the recommended type of bonds could be sold during the proposed construction schedule.

(c) To discuss certain technical details relating to methods of issuing and amortizing the bonds and to make recommendations with respect thereto.

(d) To compute the estimated annual costs of amortizing the bonds.

(e) To illustrate the degree to which the annual bond amortization or bond service costs can be met from revenues of the project and the estimated amounts which must be supplied from other sources.

(f) To demonstrate the probable effect of the financing on the State as a whole.

SECTION I

BOND FINANCING METHODS

It is quite apparent that the capital costs of the proposed Feather River Project will be required in such amounts and at such times as to preclude their being financed in full from any current revenues of the State which are likely to be available for that purpose within the foreseeable future. As a result it will undoubtedly be necessary to finance those costs by the issuance of bonds, the repayment of which can be extended over a long period of time.

Chapter IV of the State Report discusses the two types of bonds, namely revenue bonds and general obligation bonds, which might be considered as a means of financing the project. The report concludes that the use of revenue bonds to finance the project is not practicable and recommends the issuance of general obligation bonds for that purpose. We concur in those opinions.

Revenue Bonds

While revenue bond financing of certain types of revenue-producing public projects has been used successfully on an increasing scale in recent years, the proposed project in its entirety is not adaptable to that type of financing for the following reasons, among others.

In order to market revenue bonds successfully, it is necessary to demonstrate conclusively that:

1. The project can be completed within the funds provided by the bond issue.
2. The project will be completed and become operative within the time period for which interest during construction is provided from bond proceeds.
3. Annual revenues from the project will be clearly sufficient to pay all current costs including bond service, and, if future revenues are based on estimates, an added amount known as a coverage factor, sufficient to allow for a reasonable margin of error in the estimates. In addition, it is usually necessary to provide for a bond reserve fund amounting to about one year's bond service requirements, to be established from the bond proceeds or from the first revenues to be received, and to be maintained over the life of the bond issue for the added protection of the bond holders.

The nature of this project, its estimated costs, its estimated revenues and the estimated construction schedule are such that it would be impossible to meet all of the criteria set forth above to the degree required for successful marketing of revenue bonds. Even if it were possible to market revenue bonds to finance the proposed project, the interest rates and overall costs of financing would be considerably greater than those applicable to general obligation bond financing.

An attempt to finance the entire project by revenue bonds is, therefore, not recommended.

General Obligation Bonds

General obligation bonds of the State may be authorized to finance the proposed project, either by state constitutional amendment or by a specific bond act. In either case a majority vote of the electorate is required.

The payment of the interest and principal of such bonds would be secured by the full faith and credit of the State, including its power of taxation. In addition, it would be possible for the State to pledge the net revenues of the project specifically to payment of the bonds, which would further strengthen their security. Due to the high degree of security offered by bonds of this type, they would assure the State of the lowest possible interest cost. A further advantage of issuing general obligation bonds is that bonds may be sold from time to time (perhaps each years during construction periods as construction funds are required) without the necessity of selling sufficient bonds at one time to assure completion of an entire unit of the project. By arranging for sale of bonds about once each year to cover costs of construction and interest during construction, the total amount of bonds required to be issued in any year and the amount of interest payable are both reduced.

Another reason for issuing general obligation bonds, as contrasted to revenue bonds, is that the former type of bond has a broader market among investors than the latter, and consequently the possibility of market saturation is reduced.

These are the principal reasons for recommending the authorization and issuance of general obligation bonds to which the net revenues of the project are specifically pledged.

SECTION II

PROBABLE INTEREST COST AND MARKETABILITY OF BONDS

Records of past years are of limited significance in attempting to determine the probable rates of interest that will have to be paid by the State of California for its future bond issues. Nevertheless, such records represent the only fixed point of departure from which reasoning about future probabilities can commence. They have accordingly been summarized in the two tables which follow this section of the report, covering a 30-year period in which conditions of unusual prosperity, severe depression, and global war have alternated with normal peacetime economy.

Before considering the implications of these data it will be worthwhile to review some of the less tangible factors which must also be taken into account in arriving at a probable level of future interest rates reasonably applicable to the bonds of the project here under discussion.

General Factors

The Role of California in the National Economy. Despite an unbroken record of relatively rapid growth in population for over a century, California's place in the national economy did not alter essentially until the middle thirties. Traditionally the State has been a supplier of raw materials—minerals, petroleum, lumber and agricultural products—and a buyer of manufactured goods. Although the importance of California as a supplier has not appreciably diminished, great strides have been taken toward the establishment of an industrial plant within the State which has much reduced its dependence upon other manufacturing regions throughout the nation. As this economic independence develops, confidence in the financial responsibility of the State may be expected to increase in the large eastern financial markets, and such confidence should be increasingly reflected in the terms of which credit can be secured. Moreover, a period appears to be in sight when California will dominate the supply of manufactured goods to all the western states (assuming a satisfactory growth of water and power supply), and during the long prospective general growth of population in the West it is probable that a certain resilience to nationwide depression conditions will in this way be achieved in favor of the State. It is therefore likely that California will be able to continue to market sizable bond issues, and at relatively favorable rates of interest, even if generally adverse economic conditions should occur during the period contemplated for financing the Feather River Project.

Internal Changes in the State's Economy. All indications are that the population of California will continue to grow without reaching a saturation point until at least the year 2000. Growth is almost certain to concentrate in the urbanized areas and to create new cities and suburbs rather than to increase the farm and rural population. If the balance between agriculture, trade and industry within the State changes as outlined above, the trend toward concentrations of new population will be accentuated. Such movements invariably result in substantial new debt for community facilities and increased governmental expenses all around. Increased debt and governmental budgets operate in two ways to increase the costs of financing—in part by swelling the supply of bonds and thus depressing their market, and in part by increased caution on the part of buyers.

Tax-exempt Status of State Bonds. Under present laws, regulations and court decisions bonds issued by the State of California are exempt as to interest from income taxation by the Federal Government and by the State itself. This privileged status makes them quite attractive to certain types of investors at present. If the exemption of interest from income taxation should be removed by Congress or by constitutional amendment, a considerably higher interest rate would have to be offered to attract the same investors. Similarly, if income tax rates should be greatly reduced during the period under consideration, the relatively low interest rates that must be paid by the State as compared with corporate borrowers would unquestionably be raised. At present it does not seem likely either that the exemption from taxation will be removed or that the rate of taxation will be greatly lowered. All estimates of future interest costs are, however, subject to considerable error if the assumptions thus made should turn out to be incorrect.

Disasters and Depressions. Physical or economic disasters such as war, cataclysms of nature, and world-wide depression can be taken into account only generally. In arriving at an average probable interest cost over the next quarter of a century, such things must be neglected, though in arriving at a probable range outside which it seems extremely unlikely the average will fall it is possible to take them into account. As previously mentioned, the records of the past three decades cover periods of various types of abnormal economy, and the range of variation of interest rates during that time is to some extent indicative of what might be expected in the future under

similar circumstances. It is generally true that time and growth themselves tend to level out the wider fluctuations that occur in less developed economies. The more diversified and well-integrated the economy of California becomes, the less it may be expected to suffer from any single adverse condition, whether physical or economic.

Historical Background

With the foregoing general assumptions and cautions in mind, it is possible to examine the data of past years and to arrive at some conclusions, however tentative, concerning the interest rates which California will have to pay in the future for its general obligation bonds.

Volume of Bonds Sold. From 1925 through 1955 the State of California has issued at public sale general obligation bonds in the amount of $1,002,525,000. The rate of issuance has not been constant, but has been rapidly accelerating with the growth of population and the assumption of new responsibilities by the State Government. A breakdown of the amounts issued by five-year periods shows this trend very clearly.

STATE OF CALIFORNIA

AMOUNTS OF GENERAL OBLIGATION BONDS ISSUED

1925 through 1929	$33,575,000	
1930 through 1934	49,622,000	
1935 through 1939	54,998,000	
1940 through 1944	30,000	(War period)
1945 through 1949	111,000,000	
1950 through 1954	603,500,000	
Indicated 1955-1959	750,000,000	(Five times 1955 amount)

About 60 percent of all bonds sold in the past 30 years were issued during the last five-year period tabulated above. In the past six years, $385,000,000 in debt has been incurred for state aid to local school district building projects alone, or about 50 percent more than was incurred in the preceding 25 years for all state purposes. This new function of the State Government is significant in its relation to the problems created by rapid expansion of population, particularly in urbanized areas. The supply of water has in the past been traditionally regarded as a local problem, just as the provision of school buildings has been. Issuance of bonds during the next 30 years for water purposes in an amount far exceeding the total debt incurred in the past 30 years for all purposes, when viewed in this light, may be contemplated as a definite financial possibility. The total amount of debt involved appears to be equivalent to the normal financing of one decade for all other state purposes at present indicated rates. Nothing in the record indicates that such an amount could not be marketed on reasonable terms over a period of approximately three decades.

Interest Costs and Comparisons. Table 1 (at the end of this section) shows the interest cost to the State for each issue of $500,000 par value or over that has been sold in the past 30 years. The maximum rate paid during this time was 4.5 percent for bonds sold in December, 1931, and January, 1932, while the lowest interest cost was slightly under 1 percent for a relatively short-term issue sold in December, 1945. During the period covered, a general decline in interest rates has taken place; and this has been accentuated in the case of state and municipal bonds because of a steep rise in income tax rates, which has given those bonds a favored position by reason of their tax exemption.

The most recent issues to have been sold by California consisted of $30,000,000 par value each for issues of School Building and Veterans Welfare Bonds sold early in November, 1955. The school bonds had an average maturity of 14 years 10 months and were sold at an interest cost of 2.2 percent, while the veterans bonds, which had an average life of 12 years to maturity, sold at a cost of 2.1 percent. The question of date of maturity of bonds has traditionally had a considerable bearing on the rate of interest, and in general the rate has been lower for bonds of relatively short life than for long-term bonds, though this factor diminishes in importance for very long bonds. Recently the variation in interest cost attributable to this factor has been substantially reduced, though in general it is still true that higher interest must be paid for long-term than for short-term loans. In the estimation of a probable average interest rate to be paid on the proposed Feather River Project bonds, it has been necessary to make a somewhat arbitrary allowance for the effect of an average maturity of 40 years or longer. The allowance must be arbitrary because there are no standard and reliable indexes of historical market prices for municipal bonds of more than 20-year maturities.

In Table 2 are shown the reoffering prices at which bonds of 2-year, 10-year and 20-year maturities have been sold by the underwriters for selected large issues of State of California bonds since 1926. In comparison with these actual market prices are shown the average prevailing prices for certain selected issues of very high quality throughout the United States, in the column headed "Bond Buyer Index." This index is compiled weekly by the editors of the recognized trade journals serving investment bankers and dealers in municipal and state bonds, from the prevailing prices at which the obligations of 11 large and highly regarded states and municipalities have been traded during each week. The index is based upon prices of bonds of 20-year maturity. It will be noted that California general obligation bonds of that maturity have sold in most cases at prices very near to, or rather better than, this composite index of high-grade municipal securities. The data presented are necessarily incomplete, as not all issues contained bonds of each maturity shown; however, from the figures given it may be seen that lengthening of maturity in every instance

means an increase in the effective interest rate. The estimation of this effect quantitatively for extension from 20 years to 40 or more necessarily involves an element of conjecture; moreover, neither the average rate for 20-year bonds nor the range of variation between short and long bonds can be expected to remain constant in the future any more than they have in the past.

Prospective Interest Costs

In arriving at any estimate we cannot rely solely on existing market conditions, but are obliged to consider an average of sales over a period of many years. It is possible that rates will fluctuate over as large a range in the next 30 years as they did in the past 30 years. However, in our opinion they are not likely to do so, though some fluctuation in rates is inevitable. There are three important factors which we believe will operate to maintain a somewhat smaller variation than in the past, quite apart from the growing importance and economic development of California which in itself should be a stabilizing influence. These are:

1. Long-term trends in money rates of America and western Europe.
2. Governmental and Federal Reserve Board policies and controls which have come into being in relatively recent times.
3. Income tax exemption of interest from municipal bonds, assuming that tax rates will continue high and that the exemption will continue to be allowed.

After studying the available data which we consider to be relevant, and taking into consideration the longer maturity of the proposed bonds, it is our opinion that the probable average interest cost to the State for bonds of the Feather River Project over a period of approximately 30 years during which these bonds would be sold will be 2.7 percent. Accordingly, this is the rate which we have used in calculating interest costs throughout the schedules at the end of this report.

In our opinion the interest rates that will be paid by the State over the next 30 years will probably remain within the range from a minimum of 2.1 percent to a maximum of 3.3 percent. It appears to us probable that the average rate paid by the State on the proposed Feather River Project bonds will be not less than 2.4 percent nor more than 3 percent. In making these estimates we are fully aware of the pitfalls of all long-term economic forecasts, but we are equally certain that no judgment can be made of the financial feasibility of the proposed project without an estimate of interest costs based upon a study of all the relevant data available.

One additional factor in connection with interest costs remains to be mentioned and is discussed further in the following section. This is that in recent years it has become increasingly customary among state and municipal issuers of bonds, as it has long been among corporations, to make the outstanding obligations callable for payment at the option of the issuer. In this way a period of prevailing low interest rates may be utilized for refinancing bonds issued during a period of high interest rates. A judicious use of this principle and of the resulting power to refund outstanding bonds at appropriate times, with due consideration of both the rights of the bondholder and the interests of the taxpayer, is assumed throughout the balance of the discussion of this project.

Prospective Marketability

In judging the ability of financial markets to absorb bonds in the amounts contemplated, it is necessary to consider not only the total size of the proposed issue but also the projected annual sales of bonds. Under Schedule No. 1 or Schedule No. 10-A, the pattern calls for maximum sales in years 1 to 3 and 17 to 20. Schedule No. 1 calls for sales in the first three years at a level considerably above the amounts which have previously been sold by the State of California at any one time, whereas the requirements of Schedule No. 10-A during that same period do not much exceed the size of bond sales which California has twice successfully conducted (September, 1950, and February, 1953; see Table 1). On the other hand, Schedule No. 10-A calls for considerably larger sales than Schedule No. 1 in years 17 to 20, the greatest annual issue being nearly 25 percent larger than under Schedule No. 1. These two plans will be considered first, and some comment will be made upon the requirements of Schedule No. 8-A afterwards.

The size of bond issues coming to the market throughout the Nation has been noticeably increasing over a long historical period, partly as a result of increases in scope of activities of state and local governments, and partly because of general inflationary price movements operating to increase costs. Issues of $100 million to $150 million are no longer unusual; in fact, they are of almost monthly occurrence on the the national scene. Issues of over $150 million in one block are still considered exceptional, though they occur with increasing frequency and, if offered by issuers of sound credit and properly scheduled with respect to other public offerings, they cause no disruption in the market. As recently as October, 1955, a single issue of $415 million revenue bonds was sold by an Illinois authority, and on the following day $122 million Public Housing Authority bonds were bought by two competing underwriting syndicates. This recent example shows the power of the market to absorb large bond issues, but it must be considered exceptional and it would not be safe to assume that

issues of such size could be offered by a single state in several successive years with uniformly satisfactory results. At the same time it is probable that the historical increase in size of single issues will continue, and hence that it may be more feasible to offer bonds in the general pattern of Schedule No. 10-A, with its later incidence of somewhat higher amounts than are now customary, than in that of Schedule No. 1, where the initial and peak offerings are more nearly equal, but the first blocks of bonds are near the limit of ordinary size for present-day issues.

The nature of the Feather River Project is such that some flexibility exists during most years in the scheduling of work and the consequent necessity of bond sales. Special conditions of either a physical or an economic nature may make it advisable to hasten or to delay certain parts of the project as time goes on, and it may become both possible and advisable to smooth out the amounts in which bonds will be brought to market by spreading them into years for which no sales are presently scheduled, or in which such sales are now shown as relatively small. These possibilities enhance the feasibility of the financing of the project as a whole. The financial markets of the United States, in which bonds of the State of California are very well known and well regarded, have historically shown remarkable powers of recovery from the effects of general economic depression as well as from extraordinarily large demands for capital during normal times; hence it is probable that the postponement of any projected financing for such reasons would not affect the program by more than a very few months at the most.

For the Nation as a whole, from $500 million to $600 million state and municipal bonds are being sold each month, roughly one-half of these being general obligation bonds and the balance revenue issues. During the 12 months ending with November, 1955, sales of state, county, city, school district, and special district bonds within California have totaled $555 million, of which $103 million were revenue bond issues. These figures afford some indication of the relation to the proposed Feather River bond issues to the volume of bonds being marketed at present. It appears to us that if due care is exercised in selecting the dates and amounts of the issues projected under either Schedule No. 1 or Schedule No. 10-A, no great difficulty should be experienced in having them absorbed by underwriters and investors. It is assumed that the opinions and advice of well-informed investment bankers and municipal bond dealers concerning the amounts which may prudently be offered at any given time would be solicited and heeded, as to some degree the offerings of other states, authorities and corporations must be taken into account in making these determinations.

The feasibility of Schedule No. 8-A is somewhat questionable from a market standpoint because of the requirements for years 17 to 19, of $290 million, $269 million, and $329 million in these three successive years. It may be that such amounts will no longer be considered unusual at that time, but it would not appear prudent to proceed along lines which would require that to be the case. Moreover, it is likely that the circumstances in which such demands for financing would be of frequent occurrence on a national scale would be those in which inflationary costs and prices would be operative; and in such a case the amounts required to be raised for the contemplated work on the project at that time would similarly be increased beyond present estimates for the same reason. In our opinion, therefore, the feasibility of Schedule No. 8-A is dubious from the standpoint of marketability.

TABLE 1

STATE OF CALIFORNIA

SALES OF GENERAL OBLIGATION BONDS IN ISSUES OF $500,000 AND OVER 1925 TO 1955

Date of	Amount in thousands	†	Coupon (%)	Date of bonds	Life of bonds in years		Average interest cost	Date of	Amount in thousands	†	Coupon (%)	Date of bonds	Life of bonds in years		Average interest cost
					Range	Average‡							Range	Average‡	
5/ 1/25	$2,000	V	4½%	5/ 1/25	2 −21	12	4.240%	12/11/45	15,000	V	1¼%	8/ 1/45	1 −18	10	0.945%
10/15/25	2,000	V	4½	10/ 1/25	1½ −20½	11½	4.433	6/25/46	2,500	H	1½	3/ 1/46	1 −30	18*	1.291
2/10/27	2,500	V	4½	2/ 1/27	4 −20	13	4.184	7/16/46	15,000	V	1¼	4/ 1/46	2½ −19½	11	1.226
5/12/27	1,250	B	4¼	1/ 2/27	5 − 9	6½	4.001	9/24/46	1,700	H	1½	9/ 1/46	1 −30	18*	1.500
6/ 2/27	3,000	V	4¼	6/ 1/27	5 −21	13½	4.108	5/13/47	10,000	V	2	4/ 1/47	2 −21	12	1.469
11/ 3/27	2,500	V	4	11/ 1/27	5 −21	13½	3.968	6/22/48	10,000	V	2½	5/ 1/48	2 −20	12	1.710
12/ 8/27	1,000	B	4	1/ 2/27	10 −13	10½	3.896	10/19/48	25,000	V	2½	9/ 1/48	1 −20	11	1.827
2/ 9/28	4,000	V	4	2/ 1/28	4 −20	14	3.925	6/21/49	30,000	V	2¼	6/ 1/49	2 −21	12	1.924
5/31/28	4,000	V	4	5/ 1/28	4 −21	14	4.000	6/21/49	1,800	H	1½ and 3¼	9/ 1/46 and 3/ 1/49	1 −30	18*	2.312
9/ 6/28	1,000	B	4¼	1/ 2/27	14 −17	14	4.216								
10/ 4/28	4,000	V	4¼	10/ 1/28	4 −21	13½	4.231								
11/15/28	1,000	B	4¼	1/ 2/27	16 −19	17½	4.190	2/ 1/50	25,000	V	2¼	2/ 1/50	2 −21	12*	1.617
12/ 6/28	500	H	4	7/ 2/15	60	60*	4.000	5/ 3/50	50,000	S	1 to 4½	5/ 1/50	2 −26	15*	1.741
4/ 4/29	500	H	4	7/ 2/15	60	60*	4.108								
4/ 4/29	2,000	B	4½	1/ 2/27	22 −29	23	4.462	9/ 7/50	1,000	H	2¼	9/ 1/50	1 −30	18*	1.844
8/29/29	800	H	4	7/ 2/15	60	60*	4.151	9/ 7/50	50,000	V	1½ and 4	8/ 1/50	2 −21	12*	1.663
11/21/29	1,000	B	4½	1/ 2/27	27 −30	28½	4.368								
6/19/30	900	T	4½	1/ 2/29	6 −41	23½	4.242	9 /7/50	50,000	S	1½ to 4	9/ 1/50	2 −26	15*	1.759
7/ 8/30	1,250	B	4¼	1/ 2/27	30½ −35½	32½	4.121								
3/ 5/31	4,000	V	4¼	2/ 1/31	4 −21	13½	3.942	4/ 4/51	50,000	S	1½ to 4	5/ 1/51	2 −26	15*	1.898
4/ 9/31	750	H	4	7/ 2/15	58	58*	3.947								
4/23/31	1,147	P	4¼	1/ 2/29	4 − 9	6½	3.672	7/11/51	25,000	V	1½ to 4	8/ 1/51	2 −21	12*	1.890
6/11/31	4,000	V	4	6/ 1/31	4 −21	13½	3.673								
7/30/31	1,753	P	4	1/ 2/29	9½ −16½	13	3.774	7/11/51	1,500	H	2¼	3/ 1/51	1 −30	18*	2.127
11/ 2/31	3,000	V	4	10/ 1/31	14½ −20½	18½	4.000	1/ 9/52	25,000	V	1½ to 4	2/ 1/52	1 −20	12*	1.728
12/17/31	2,750	V	4½	12/ 1/31	4 −21	15½	4.500								
1/22/32	2,025	V	4½	12/ 1/31	7 −17	14	4.500	1/ 9/52	25,000	S	1½ to 4	11/ 1/51	1 −25	15*	1.803
3/10/32	1,225	V	4½	12/ 1/31	7 −12	9½	4.430								
5/19/32	3,000	V	4½	4/ 1/32	5 −21½	14½	4.362	6/ 4/52	50,000	S	1½ to 4	5/ 1/52	2 −26	15*	1.868
12/ 1/32	725	P	4¼	1/ 2/39	18 −21	19½	3.960								
10/10/33	6,000	U	4¼	10/ 1/33	5 − 7	6	4.250	10/29/52	25,000	S	2 to 4	11/ 1/52	2 −26	15*	2.094
2/ 1/34	6,000	U	4½	2/ 1/34	7½ − 9½	8½	4.028	2/ 3/53	100,000	V	2 to 2½	2/ 1/53	1½ −20½	12*	2.416
6/ 1/34	8,000	U	3¾	6/ 1/34	10 −13	11½	3.467								
7/ 2/34	500	H	4	7/ 2/15	55	55*	3.818	6/24/53	25,000	S	2¾ to 5	5/ 1/53	2 −26	15*	3.013
4/11/35	24,000	U	3½	4/11/35	5 −14	9½	2.897								
6/ 6/35	5,000	V	3	6/ 1/35	2 −17	9	2.875	6/24/53	1,000	H	3	3/ 1/53	1 −30	18*	3.115
3/12/36	5,000	V	2¾	2/ 1/36	2 −18	9	2.502	1/13/54	50,000	V	1¾ and 2	2/ 1/54	2 −24	12*	1.933
6/25/36	5,000	V	2¾	6/ 1/36	2 −18	9	2.554								
10/22/36	700	H	4	7/ 2/15	53	53*	3.657	4/21/54	50,000	S	1 to 5	5/ 1/54	2 −26	15*	2.194
1/ 7/37	3,000	V	2¼	1/ 1/37	1 −17	8	2.017	1/ 5/55	60,000	V	¼ to 5	2/ 1/55	2 −21	12*	2.030
4/ 8/37	3,000	V	2¾	4/ 1/37	2 −13	9	2.750	4/27/55	30,000	S	¼ to 5	5/ 1/55	1½ −25½	14*	2.052
6/24/37	3,000	V	3	6/ 1/37	2 −13	6½	2.571	11/ 2/55	30,000	S	¼ to 5	11/ 1/55	2 −26	14*	2.209
1/ 6/38	3,000	V	2¾	1/ 1/38	1 −16	8½	2.285	11/ 2/55	30,000	V	1¾ to 5	12/ 1/55	2 −21	12*	2.137
1/ 5/39	3,000	V	2¾	1/ 1/39	1 −15	8½	2.163								

* Bonds callable or partly callable; average life and interest cost figured to maturity.

† Purpose of bonds:
B—State Buildings and University Buildings
H—San Francisco Harbor Improvement
P—State Parks
S—State School Aid
T—Tenth Olympiad
U—Unemployment Relief
V—Veterans' Welfare

‡ Approximate average to nearest half-year.

TABLE 2

REOFFERING PRICES OF CALIFORNIA BOND ISSUES

(SELECTED ISSUES OF $500,000 OR OVER)

Date of sale	Amount in thousands	†	Coupon	Maturity			Bond buyer index*	Date of sale	Amount in thousands	†	Coupon	Maturity			Bond buyer index*
				2-Year	10-Year	20-Year						2-Year	10-Year	20-Year	
2/10/27	$2,500	V	4½%		4.00%	4.00%	4.05%	1940							
5/12/27	1,250	B	4¼		3.90‡		3.91	through	No sales occured						
6/ 2/27	3,000	V	4¼		3.90	3.90	3.92	1944							
11/ 3/27	2,500	V	4		3.85	3.85	3.92	12/11/45	$15,000	V	1¼%	0.50%	0.85%		1.21%
12/ 8/27	1,000	B	4		3.75		3.89	6/25/46	2,500	H	1½		0.95	1.20%	1.17
2/ 9/28	4,000	V	4		3.80	3.80	3.83	7/16/46	15,000	V	1¼	0.70	1.00	1.25	1.17
5/31/28	4,000	V	4		4.00	4.00	3.87	9/24/46	1,700	H	1½		1.25	1.50	1.47
9/ 6/28	1,000	B	4¼		4.10		4.15	6/13/47	10,000	V	2	0.70	1.20	1.60	1.65
10/ 4/28	4,000	V	4¼		4.10	4.10	4.12	6/22/48	10,000	V	2½	0.80	1.45	1.80	2.02
11/15/28	1,000	B	4¼			4.10	4.12	10/19/48	25,000	V	2½	0.80	1.50	2.00	2.21
4/ 4/29	2,000	B	4½			4.35‡	4.31	6/21/49	30,000	V	2¼	0.85	1.50	2.00	1.96
8/29/29	800	H	4			4.35	4.40	6/21/49	1,800	H	Various		1.60	2.05	
6/19/30	900	T	4½		4.00	4.05	4.13	2/ 1/50	25,000	V	2¼	0.75	1.30	1.80	1.85
3/ 5/31	4,000	V	4¼		3.75	3.80	3.95	5/ 3/50	50,000	S	Various	0.65	1.35	1.80	1.84
4/ 9/31	750	H	4			3.75	3.82	9/ 7/50	1,000	H	2¼		1.35	1.70	1.66
4/23/31	1,147	P	4¼		3.70		3.75	9/ 7/50	50,000	V	Various	1.00	1.40	1.75	1.66
6/11/31	4,000	V	4		4.45	3.55	3.60	9/ 7/50	50,000	S	Various	1.00	1.40	1.75	1.66
7/30/31	1,753	P	4		3.55		3.70	4/ 4/51	50,000	S	Various	1.20	1.50	1.80	1.77
12/17/31	2,750	V	4½			4.35	4.23	7/11/51	25,000	V	Various	1.20	1.60	1.95	2.02
3/10/32	1,225	V	4½		4.25		4.61	7/11/51	1,500	H	2¼		1.60	1.95	2.02
5/19/32	3,000	V	4½		4.20	4.20	4.30	1/ 9/52	25,000	V	Various	1.15	1.60	1.85	1.92
2/ 1/34	6,000	U	4½		3.80		4.06	1/ 9/52	25,000	S	Various	1.05	1.50	1.80	1.92
6/ 1/34	8,000	U	3¾		3.20		3.61	6/ 4/52	50,000	S	Various	1.05	1.50	1.90	1.91
4/11/35	24,000	U	3½		2.60		2.90	10/29/52	25,000	S	Various	1.10	1.65	2.10	2.20
6/ 6/35	5,000	V	3	1.00%	2.75	3.00‡	2.98	2/ 3/53	100,000	V	Various	1.10	2.00	2.55	2.30
3/12/36	5,000	V	2¾	0.90	2.40	2.75‡	2.66	6/24/53	25,000	S	Various	2.00	2.65	2.95	2.85
6/25/36	5,000	V	2¾	0.85	2.45	2.75‡	2.61	6/24/53	1,000	H	3		2.65	2.95	2.85
10/22/36	700	H	4			2.70	2.53	1/13/54	50,000	V	Various	1.10	1.65	2.10	2.37
1/ 7/37	3,000	V	2½	0.50	2.00		2.35	4/21/54	50,000	S	Various	0.85	1.45	2.30	2.31
4/ 8/37	3,000	V	2¾	1.60	2.75		2.90	1/ 5/55	60,000	V	Various	0.75	1.65	2.20	2.38
1/ 6/38	3,000	V	2¾	0.90	2.20		2.75	4/27/55	30,000	S	Various	1.10	1.75	2.10	2.26
1/ 5/39	3,000	V	2¾	0.65	2.10		2.36	11/ 2/55	30,000	S	Various	1.50	1.75	2.20	2.30
								11/ 2/55	30,000	V	Various	1.50	1.75	2.20	2.30

* Index of prices of eleven high-grade municipal bonds of 20-year maturity.

† Purpose of bonds:
B—State Buildings and University Buildings
H—San Francisco Harbor Improvement
P—State Parks
S—State School Aid
T—Tenth Olympiad
U—Unemployment Relief
V—Veterans' Welfare

‡ Approximate.

SECTION III

EXPLANATION OF FINANCIAL ANALYSES

The State Report on the Feather River Project contains five separate financial analyses, each of which is applicable to a physically different project or construction schedule. However, in each analysis in the State Report the following uniform assumptions as to financing were made:

1. That the general obligation bonds to be sold to finance the project would bear interest at an average rate of 2½ percent per annum.

2. That at the beginning of the first year of each construction step or stage, a sufficient number of bonds would be issued to pay construction costs during that year plus interest for that year on the construction costs and that in each subsequent year during a construction step, a sufficient number of bonds would be issued to pay construction costs for that year plus interest for that year on all bonds then being issued and those previously issued for that construction step.

3. That during the first 10 years after issuance of each block of bonds, no principal would become due on those particular bonds, but during the ensuing 30-year period the bonds would be amortized on a straight-line basis (equal annual bond service).

4. That net revenues of the project would be applied toward annual debt service and any deficiency met by the State's General Fund.

Schedule 0 of this report, which is applicable to Route 1 plan, was prepared for comparative purposes only with substantially the same assumptions used in the State Report, with the following exceptions:

(a) Construction cost estimates and time schedules and estimates of net revenues are those supplied by Bechtel Corporation.

(b) An average bond interest rate of 2.7 percent instead of the 2.5 percent rate shown in the State Report is assumed.

(c) Interest during construction has been computed on the bonds outstanding and to be issued during each year for each construction step and not on the construction cost alone. For example, if $100,000 is required for construction costs, then bonds in the amount of $102,775 must be issued to provide construction costs and interest at 2.7 percent for one year on the bonds being issued, rather than $102,700 which would be the result were the interest computed on construction costs alone.

(d) During each construction year it is assumed that an average of one-half of the funds provided from bond sales that year will be invested in short term U. S. Government obligations at a rate of 2 percent per annum and that such earnings are to be deducted from the amounts required for bond interest during that year. The reinvestment of idle funds during construction was not taken into account in the State Report.

Interest During Construction

It is to be noted that in both the State Report and Schedule 0 referred to above, the assumption is made that each year during a construction step (the period of time between the beginning of construction of each unit of the project and its completion) bonds will be issued in amounts sufficient to meet construction costs during that year plus interest for that year on both the bonds then being issued and on any bonds issued in a previous year for that construction step. The State's method of providing interest during construction from bond proceeds is a departure from the normally accepted methods, in that each year after the first year of a construction step, bonds must be issued to provide interest payments for that year on bonds previously issued for that construction step. It is conceivable that, due to an unfavorable bond market or necessary changes in construction schedules during a construction step, it may be inadvisable to issue bonds during the first six months of a particular year, yet under this method of providing interest during construction it would be necessary either to issue such bonds in an amount at least sufficient to pay interest on bonds previously issued for that construction step, or to provide such interest from the General Fund. The interest to be saved by such a procedure is extremely nominal, particularly when reinvestment of idle funds is taken into consideration. In addition, when the results are projected into a bond amortization schedule the variations become considerable in the annual sums required from the General Fund.

In preference to this method of providing interest during construction, it is suggested that each sale of bonds include a sufficient amount to pay interest on those bonds for the estimated number of years it will take to complete the unit of the project for which they are issued.

This method of providing interest during construction is used in the computations shown on Schedules 1, 8-A, and 10-A.

In computing the schedules, credits have been taken for the reinvestment in short-term government bonds

of one-half of the funds provided for construction and interest during each construction year at a rate of 2 percent per annum. This is based on the theory that if sufficient bonds are sold at the beginning of a construction year to provide for construction costs and interest during construction, an average of one-half of the funds will be available for reinvestment in short-term obligations during the year. The credits for such earnings are reflected in the amount of bonds to be sold in that year.

Bond Amortization

As previously mentioned, the State Report and Schedule 0 of this report assume that no principal payments would be made on bonds during the first 10 years after their issuance, after which they would be amortized on a straight-line basis (equal annual debt service) over the next 30-year period. This assumption, used for illustrative purposes in Schedule 0, causes most of the obligation of the general fund to occur during the earlier and middle years of the bond amortization schedule, after which substantial surplus earnings are predicted for the balance of the amortization period.

We have developed a financing program that provides for amortization coinciding more closely with project revenues, normal growth factors, and well within the expected life of the project facilities, with amortization to be completed within 70 years from commencement of the project. The State program provided a heavier annual bond service requirement in the initial stages of the project than we believe necessary. Also, by shifting a greater proportion of the debt service requirements to later years, the annual amounts required to meet such service should represent a lesser burden in relation to population, wealth, or state income because of the growth factors involved.

On the basis of this reasoning Schedules 1, 8-A and 10-A, applicable to Routes 1, 8-A and 10-A respectively, have been prepared. They show by years the estimated construction costs, the estimated amounts of bonds required to be issued to pay construction costs and interest during construction, the amounts of interest and principal payments each year, the amounts of estimated project revenues available for debt service, and the indicated deficiencies, if any, proposed to be provided by the State's General Fund.

In preparing the schedules, the following assumptions as to amortization of the bonds have been made:

1. That the total costs of the project will be amortized during a period of 70 years from date of issuance of the first series of bonds to be sold.
2. That no principal will be paid on any series of bonds for the first 10 years after their issuance.
3. That commencing with the eleventh year after issuance the amounts of bonds represented by each series will be amortized on a straight-line basis to the seventieth year. That is to say, the amounts of bonds issued in project year one would be amortized over a 60-year period commencing with the year 11; the amounts of bonds issued in project year two would be amortized over a 59-year period commencing with the year 12; etc.

This does not imply that each series of bonds issued will have a final maturity date in the year 70, but that the amounts of bonds represented by each series will, in effect, be amortized to the year 70 or earlier, by revenues if sufficient to do so, or by a suitable refunding operation to take place upon the date of their final maturity if required. This procedure contemplates the issuance of term bonds having a maximum life of not to exceed 50 years with minimum annual sinking fund requirements commencing with the eleventh year after issuance approximately equal to the annual amounts which would be required were they to be amortized on a straight-line basis to the year 70. Obviously, under such a procedure the bonds of any series whose term expires prior to the year 70 would not be completely amortized when due. However, any unamortized amount could then be refunded with an equivalent amount of new bonds to be amortized over the remaining number of years to the year 70. This type of fiscal procedure is practiced extensively by the Federal Government and by many private utilities and corporations.

While it may prove advisable to issue a limited amount of each bond series, as serially maturing bonds, it is believed that the major portion should be term bonds with a single maturity date and subject to prior redemption from sinking fund moneys.

Because the bonds to be issued under any reasonable plan of amortization will have an average life considered among investors as being long-term, it is believed that the procedure suggested above will not affect adversely the interest rates to be paid on the bonds.

In addition, such a plan of bond amortization provides a higher degree of flexibility insofar as annual bond service requirements and possible refunding operations are concerned. It makes it possible to gear annual bond service more closely to project revenues and consequently reduces the variations in annual amounts which must be provided from the State's General Fund. It also provides a more convenient means by which refunding operations, designed either to refund maturing bonds or to take advantage of lower interest rates, may be accomplished.

Call and Redemption Features

Should the major portion of the bonds be issued in the form of term bonds, as suggested above, it would undoubtedly be advisable to provide means by which

a part of the bonds may be called and redeemed prior to their respective maturity dates, so that advantage may be taken of any surplus revenues which may accrue from time to time or of any lower interest rates which might become available during their life. The exact terms and conditions under which bonds may be redeemed prior to maturity are stipulated at the time the bonds are issued, and the nature of those terms and conditions are dependent upon a number of factors then existing or likely to occur. They frequently involve the payment of a premium to protect the bond purchaser's yield and sometimes restrict the funds to be used for redemptions to certain sources. Due to the technical nature of these features, no attempt is made in this report to make detailed recommendations in this regard.

Legislation

Suitable provisions relating to maturities, redemption prior to maturity, refunding, and all other features essential to the marketing of such bond issues must be included in any legislative act or constitutional amendment authorizing bonds for the project. In drafting legislation applicable to issuance of the bonds, the advice and opinions of recognized municipal bond counsel should be obtained.

SECTION IV

RELATION OF PROJECT FINANCING TO THE STATE ECONOMY

The State of California has tremendous capacity for raising capital through issuance of securities against its taxing powers. California is second only to New York in population and is outranked only by New York, Illinois and Ohio in assessed valuation. It possesses extensive natural resources and a highly diversified economy.

Rapid growth and expansion have been the rule throughout the State's history, with every indication that this trend will continue indefinitely. The only apparent restraint on growth is the ability of the State to provide necessary facilities in the form of transportation, schools, water supplies and governmental services. The State's past record in this respect has been excellent through progressive legislation, sound fiscal policies, aggressive attacks on current problems, and long-range planning to meet future needs.

Per capita wealth is considerably above the national average. The debt burden is modest and taxes are spread over a broad base. While California collects the largest amount of state taxes in the union, over half is used for subventions to local units, with the result that local taxation is relatively low.

During the fiscal year ending June 30, 1955, in excess of 1.33 billion dollars was collected by the State through taxes, fees and licenses, excluding unemployment contributions of almost 180 million and over 66 million dollars released from impounded tideland oil royalties. Local governmental units collected an additional 1.14 billion dollars, making the total local and state taxes collected about 2.5 billion dollars from an average population of about 12.5 million persons. This represents a tax burden of approximately $200 per capita distributed about equally between local and State Government.

Total income for the State's General Fund during the 1954-55 fiscal year was 878 million dollars. These revenues included 20 million dollars from release of impounded tideland oil funds. General Fund expenditures were 857 million dollars with 268 million being for state operations and 589 million for payments to local agencies. Large surpluses have been prevalent in the general fund over the past 10 to 15 years. At the end of June 30 the general fund surplus and the revenue deficiency reserve fund contained a total of about 150 million dollars.

Bonded debt of the State of California on June 30, 1955, was $767,344,000. This included all outstanding bonds that are general obligations of the State, which are summarized as follows:

Purpose	*Outstanding June 30, 1955*
State buildings and parks	$6,620,000
State highways	16,800,000
Tenth Olympiad	400,000
Public school buildings	322,600,000
San Francisco Harbor improvement	21,649,000
Veterans' farm and home purchases	389,265,000
Total	$767,344,000

The San Francisco Harbor and the veterans' bonds are serviced from revenues produced by these agencies' respective activities, without drawing upon the General Fund tax revenues. The public school bonds are used for loans to local school districts which are expected to be repaid if possible, but the actual amount that will be returned cannot be accurately predicted. Any repayment, to whatever extent made, must come from local taxation, so from the standpoint of individual tax burden the distinction is only in whether the debt is serviced from direct state taxation or through refunds derived from local taxation.

Elimination of the self-liquidating harbor and veterans' bond issues leaves a bonded debt of $356,430,000 that is a direct obligation of the General Fund, excluding certain sinking funds and assignments of revenue that do not significantly alter the over-all debt picture. This represents a net debt of about $27 per capita for the 13 million people estimated to be in the State on June 30, 1955.

Per capita personal income in California for 1954 was $2,162 compared with the national average of $1,770. Total assessed valuation in 1955 was 18.3 billion dollars or about $1,400 per capita. Thus, it can be seen that the State's debt is well within the income and resources of the population. The net debt is only about 2 percent of the assessed valuation, which is reported to represent less than one-third of fair market value.

The following forecasts of population to the year 2000 have been supplied by the Stanford Research Institute through Bechtel Corporation:

Year	*Population*
1960	15,629,000
1965	18,059,000
1970	20,696,000
1975	23,565,000
1980	26,700,000
1985	30,100,000
1990	33,700,000
1995	37,500,000
2000	41,500,000

By using the population forecasts shown above, an indication of the effect of the proposed Feather River Project financing on the State in terms of per capita

ESTIMATED DEBT AND OBLIGATION OF THE GENERAL FUND TO BE INCURRED BY FINANCING THE FEATHER RIVER PROJECT
(Per Capita) [a]

	Year	Route 1		Route 8A		Route 10A	
		Total outstanding project debt	Annual General Fund obligation	Total outstanding project debt	Annual General Fund obligation	Total outstanding project debt	Annual General Fund obligation
5	1965 [b]	$17.49	$.39	$17.24	$.37	$18.62	$.41
10	1970	40.27	.35	20.21	.23	21.62	.26
15	1975	38.81	.38	21.20	.24	22.24	.30
20	1980	33.10	.35	19.36	.26	19.07	.26
21*	1981*	57.38*	.63*	60.56*	.67*	51.85*	.50*
25	1985	50.75	.17	54.08	.18	46.25	.21
30	1990	45.11	.25	47.65	.22	42.79	.17
40	2000	32.24	.03	32.81	.01	29.62	.02
50	2010	24.59	.08	25.01	.02	22.57	.03
60	2020	14.58	.09	14.83	.02	13.38	.04
70	2030	1.51	.10	1.53	.03	1.38	.05

[a] Based on Stanford Research Institute forecasts of population of California to the year 2000, with no increase reflected thereafter.
[b] For the purposes of per capita comparisons the first project year is assumed to be 1961.
* Maximum per capita point.

debt and annual General Fund obligations may be obtained for each of the three plans of construction under consideration.

As shown above, the indicated maximum per capita debt to be outstanding for the Feather River Project ranges from $51.85 for Route No. 10-A to $60.56 for Route No. 8-A. The present outstanding debt of the State of $767,344,000 is equal to about $59.02 per capita based on a present estimated population of 13 million.

The indicated maximum annual General Fund obligation applicable to the project is about 67 cents per capita, as contrasted to present annual state taxes, fees and licenses of about $106.40 per capita, and total state and local government taxes, fees and licenses of nearly $200 per capita.

When compared with a present annual General Fund budget of about $900 million, the annual General Fund obligations to be incurred for the project as shown on the schedules at the end of this report appear to be reasonable.

SECTION V

SUMMARY AND CONCLUSIONS

Estimated capital costs of the proposed Feather River Project are such as to require the issuance of bonds. Prospective project revenues during the initial stages preclude consideration of revenue bonds as a means of financing. The issuance of State of California general obligation bonds, to which net revenues of the project are specifically pledged, is recommended as being the most economical and practical means of financing. Any project legislation should be enacted with great care and consideration so that necessary flexibility in financing procedure will be provided.

Funds for the payment of interest and principal of the bonds would be derived to the extent possible from net project revenues and any balance from the State's General Fund.

We have developed a financing program that provides for amortization coinciding more closely with project revenues, normal growth factors, and well within the expected life of the project facilities, with amortization to be completed within 70 years from commencement of the project. The state program provided a heavier annual bond service requirement in the initial stages of the project than we believe necessary.

The use of term bonds having fixed maturity dates of not to exceed 50 years from date of issuance, with suitable provisions for prior redemption and refunding, is recommended as a means of providing satisfactory flexibility in the financing program.

Judging from past records and present prospects, it is estimated that the bonds should be salable at an average interest cost of 2.7 percent during the approximate 30-year construction period.

Maximum annual bond sales projected for Routes No. 1 and 10-A do not exceed greatly the amounts of many single bond issues sold elsewhere in recent years and consequently should not present difficulties insofar as marketability is concerned. Those projected for Route No. 8-A in the 17th to 19th years, being considerably greater in magnitude, may do so.

The financial requirements of the project appear to be moderate, in relation to probable population, income and wealth of the State.

Therefore, in conclusion, it is our considered judgment that, subject to the conditions outlined herein, it is feasible to finance the Feather River Project with general obligation bonds of the State.

Yours very truly,

BLYTH & CO., INC.
By JOHN INGLIS

STONE & YOUNGBERG
By DON M. DAVIS

HELLER, BRUCE & CO.
By RICHARD C. VAN HOUTEN

FEATHER RIVER PROJECT SCHEDULE No. 0

FINANCIAL ANALYSIS

ROUTE 1—STATE'S HIGH LINE ROUTE TO BARRETT RESERVOIR

Using State's Bond Amortization Method

(000 omitted)

Project year	Construction funds required [a]	Bond issue required [b]	Cumulative bonds issued	Bonds outstanding [c]	Interest payable at 2.7 percent	Principal payable	Total bond service payable	Net revenue available from project [a]	General fund obligation	Excess net project revenues
1	$155,813	$158,507	$158,507	--	--	--	--	--	--	--
2	167,882	175,065	333,572	--	--	--	--	--	--	--
3	148,432	159,695	493,267	$7,317	$198	--	$198	--	$198	--
4	38,883	44,227	537,494	315,003	8,505	--	8,505	$1,528	6,977	--
5	36,371	42,728	580,222	315,406	8,516	--	8,516	1,528	6,988	--
6	106,420	114,987	695,209	315,406	8,516	--	8,516	1,528	6,988	--
7	89,762	100,964	796,173	315,406	8,516	--	8,516	1,528	6,988	--
8	29,130	31,147	827,320	739,595	19,969	--	19,969	15,436	4,533	--
9	395	402	827,722	827,320	22,338	--	22,338	16,865	5,473	--
10	--	--	827,722	827,722	22,348	--	22,348	15,278	7,070	--
11	--	--	827,722	827,722	22,348	$3,498	25,846	15,818	10,028	--
12	20,562	20,918	848,640	824,224	22,254	7,454	29,708	16,501	13,207	--
13	31,645	32,757	881,397	816,770	22,053	11,178	33,231	17,525	15,706	--
14	36,793	38,863	920,260	805,592	21,751	12,456	34,207	20,678	13,529	--
15	--	--	920,260	885,674	23,913	13,736	37,649	20,324	17,325	--
16	--	--	920,260	871,938	23,542	16,643	40,185	20,159	20,026	--
17	128,105	130,320	1,050,580	855,295	23,093	19,319	42,412	21,612	20,800	--
18	153,412	159,584	1,210,164	835,976	22,571	20,528	43,099	21,770	21,329	--
19	170,601	181,283	1,391,447	815,448	22,017	21,092	43,109	21,899	20,210	--
20	195,806	211,599	1,603,046	794,757	21,458	21,661	43,119	22,018	21,101	--
21	--	--	1,603,046	1,455,481	39,298	22,246	61,544	32,480	29,064	--
22	--	--	1,603,046	1,433,235	38,698	23,307	62,005	35,274	26,731	--
23	--	--	1,603,046	1,409,928	38,068	24,660	62,728	38,444	24,284	--
24	3,716	3,780	1,606,826	1,385,268	37,402	26,183	63,585	40,384	23,201	--
25	17,566	17,972	1,624,798	1,359,085	36,695	26,890	63,585	45,540	18,045	--
26	31,678	32,811	1,657,609	1,332,195	35,969	27,616	63,585	42,919	20,666	--
27	--	--	1,657,609	1,359,142	36,697	31,237	67,934	46,414	21,520	--
28	--	--	1,657,609	1,327,905	35,853	35,601	71,454	49,520	21,934	--
29	3,089	3,142	1,660,751	1,292,304	34,892	40,561	75,453	52,125	23,328	--
30	15,371	15,722	1,676,473	1,251,743	33,797	46,324	80,121	52,769	27,352	--
31	28,226	29,221	1,705,694	1,205,419	32,546	47,575	80,121	53,003	27,118	--
32	--	--	--	1,205,929	32,560	48,859	81,419	55,212	26,207	--
33	--	--	--	1,157,070	31,241	50,178	81,419	57,096	24,323	--
34	--	--	--	1,106,892	29,886	51,617	81,503	57,494	25,009	--
35	--	--	--	1,055,275	28,492	53,408	81,900	60,427	21,473	--
36	--	--	--	1,001,867	27,050	55,574	82,624	61,282	21,342	--
37	--	--	--	946,293	25,550	57,074	82,624	63,950	18,674	--
38	--	--	--	889,219	24,009	58,615	82,624	63,568	19,056	--
39	--	--	--	830,604	22,426	60,267	82,693	62,410	20,283	--
40	--	--	--	770,337	20,799	62,241	83,040	62,410	20,630	--
41	--	--	--	708,096	19,119	56,789	75,908	61,213	14,695	--
42	--	--	--	651,307	17,585	49,734	67,319	61,213	6,106	--
43	--	--	--	601,573	16,242	43,242	59,484	61,213	--	$1,729
44	--	--	--	558,331	15,075	42,239	57,314	61,213	--	3,899
45	--	--	--	516,092	13,934	41,283	55,217	61,213	--	5,996
46	--	--	--	474,809	12,820	36,756	49,576	61,014	--	11,438
47	--	--	--	438,053	11,827	32,796	44,623	61,014	--	16,391
48	--	--	--	405,257	10,942	32,153	43,095	61,014	--	17,919
49	--	--	--	373,104	10,074	33,001	43,075	61,014	--	17,939
50	--	--	--	340,103	9,183	33,892	43,075	61,014	--	17,939
51	--	--	--	306,211	8,268	34,807	43,075	60,814	--	17,739
52	--	--	--	271,404	7,328	34,721	42,049	60,814	--	18,765
53	--	--	--	236,683	6,390	34,052	40,442	60,814	--	20,372
54	--	--	--	202,631	5,471	33,064	38,535	60,814	--	22,279
55	--	--	--	169,567	4,578	33,957	38,535	60,814	--	22,279
56	--	--	--	135,610	3,661	34,874	38,535	60,614	--	22,079
57	--	--	--	100,736	2,720	29,421	32,141	60,614	--	28,473
58	--	--	--	71,315	1,926	22,386	24,312	60,614	--	36,302
59	--	--	--	48,929	1,321	14,097	15,418	60,614	--	45,196
60	--	--	--	34,832	940	4,097	5,037	60,614	--	55,577
61	--	--	--	30,735	830	4,207	5,037	60,415	--	55,378
62	--	--	--	26,528	716	4,321	5,037	60,415	--	55,378
63	--	--	--	22,207	600	4,437	5,037	60,415	--	55,378
64	--	--	--	17,770	480	4,371	4,851	60,415	--	55,564
65	--	--	--	13,399	362	3,607	3,969	60,415	--	56,446
66	--	--	--	9,792	264	2,095	2,359	60,205	--	57,846
67	--	--	--	7,697	208	2,151	2,359	60,205	--	57,846
68	--	--	--	5,546	150	2,209	2,359	60,205	--	57,846
69	--	--	--	3,337	90	2,115	2,205	60,205	--	58,000
70	--	--	--	1,222	33	1,222	1,255	60,205	--	58,950
	$1,609,658	$1,705,694			$1,148,971	$1,705,694	$2,854,665	$3,106,091	$699,517	$950,943

[a] Based on estimates supplied by Bechtel Corp.
[b] Includes funds for bond interest during construction.
[c] Excluding bonds outstanding upon which interest is provided from bond sale proceeds.

FEATHER RIVER PROJECT SCHEDULE No. 1

FINANCIAL ANALYSIS

ROUTE 1—STATE'S HIGH LINE ROUTE TO BARRETT RESERVOIR

(000 omitted)

Project year	Construction funds required [a]	Bond issue required [b]	Cumulative bonds issued	Bonds outstanding [c]	Interest payable at 2.7 percent	Principal payable	Total bond service payable	Net revenue available from project [a]	General fund obligation	Excess net project revenues
1	$155,813	$176,972	$176,972	--	--	--	--	--	--	--
2	167,882	183,458	360,430	--	--	--	--	--	--	--
3	148,432	156,558	516,988	$7,320	$198	--	$198	--	$198	--
4	38,883	43,071	560,059	315,503	8,519	--	8,519	$1,528	6,991	--
5	36,371	39,150	599,209	315,906	8,529	--	8,529	1,528	7,001	--
6	106,420	111,900	711,109	315,906	8,529	--	8,529	1,528	7,001	--
7	89,762	92,346	803,455	315,906	8,529	--	8,529	1,528	7,001	--
8	29,130	29,634	833,089	745,239	20,121	--	20,121	15,436	4,685	--
9	395	402	833,491	833,089	22,493	--	22,493	16,865	5,628	--
10	--	--	833,491	833,491	22,504	--	22,504	15,278	7,226	--
11	--	--	833,491	833,491	22,504	$1,211	23,715	15,818	7,897	--
12	20,562	22,133	855,624	832,280	22,471	2,543	25,014	16,501	8,513	--
13	31,645	33,101	888,725	829,737	22,402	3,758	26,160	17,525	8,635	--
14	36,793	37,429	926,154	825,979	22,301	4,185	26,486	20,678	5,808	--
15	--	--	926,154	914,457	24,690	4,605	29,295	20,324	8,971	--
16	--	--	926,154	909,852	24,566	5,636	30,202	20,159	10,043	--
17	128,105	142,023	1,068,177	904,216	24,414	6,564	30,978	21,612	9,366	--
18	153,412	165,137	1,233,314	897,652	24,237	6,999	31,236	21,770	9,466	--
19	170,601	178,442	1,411,756	890,653	24,048	7,191	31,239	21,899	9,340	--
20	195,806	199,192	1,610,948	883,863	23,864	7,386	31,250	22,018	9,232	--
21	--	--	1,610,948	1,560,870	42,143	7,585	49,728	32,480	17,248	--
22	--	--	1,610,948	1,553,285	41,939	8,012	49,951	35,274	14,677	--
23	--	--	1,610,948	1,545,273	41,722	8,574	50,296	38,444	11,852	--
24	3,716	4,000	1,614,948	1,536,699	41,491	9,209	50,700	40,384	10,316	--
25	17,566	18,374	1,633,322	1,527,490	41,242	9,458	50,700	45,540	5,160	--
26	31,678	32,226	1,665,548	1,518,032	40,987	9,713	50,700	42,919	7,781	--
27	--	--	1,665,548	1,562,919	42,199	11,696	53,895	46,414	7,481	--
28	--	--	1,665,548	1,551,223	41,883	14,091	55,974	49,520	6,454	--
29	3,089	3,325	1,668,873	1,537,132	41,503	16,808	58,311	52,125	6,186	--
30	15,371	16,078	1,684,951	1,520,324	41,049	19,977	61,026	52,769	8,257	--
31	28,226	28,714	1,713,665	1,500,347	40,509	20,517	61,026	53,003	8,023	--
32	--	--	--	1,527,947	41,255	21,070	62,325	55,212	7,113	--
33	--	--	--	1,506,877	40,686	21,639	62,325	57,096	5,229	--
34	--	--	--	1,485,238	40,101	22,288	62,389	57,494	4,895	--
35	--	--	--	1,462,950	39,500	23,197	62,697	60,427	2,270	--
36	--	--	--	1,439,753	38,873	24,389	63,262	61,282	1,980	--
37	--	--	--	1,415,364	38,215	25,047	63,262	63,950	--	$688
38	--	--	--	1,390,317	37,539	25,723	63,262	63,568	--	306
39	--	--	--	1,364,594	36,844	26,484	63,328	62,410	918	--
40	--	--	--	1,338,110	36,129	27,537	63,666	62,410	1,256	--
41	--	--	--	1,310,573	35,385	28,913	64,298	61,213	3,085	--
42	--	--	--	1,281,660	34,605	29,693	64,298	61,213	3,085	--
43	--	--	--	1,251,967	33,803	30,495	64,298	61,213	3,085	--
44	--	--	--	1,221,472	32,980	31,318	64,298	61,213	3,085	--
45	--	--	--	1,190,154	32,134	32,164	64,298	61,213	3,085	--
46	--	--	--	1,157,990	31,266	33,032	64,298	61,014	3,284	--
47	--	--	--	1,124,958	30,374	33,923	64,297	61,014	3,283	--
48	--	--	--	1,091,035	29,458	34,839	64,297	61,014	3,283	--
49	--	--	--	1,056,196	28,517	35,780	64,297	61,014	3,283	--
50	--	--	--	1,020,416	27,551	36,746	64,297	61,014	3,283	--
51	--	--	--	983,670	26,559	37,739	64,298	60,814	3,484	--
52	--	--	--	945,931	25,540	38,758	64,298	60,814	3,484	--
53	--	--	--	907,173	24,494	39,804	64,298	60,814	3,484	--
54	--	--	--	867,369	23,419	40,879	64,298	60,814	3,484	--
55	--	--	--	826,490	22,315	41,983	64,298	60,814	3,484	--
56	--	--	--	784,507	21,182	43,116	64,298	60,614	3,684	--
57	--	--	--	741,391	20,018	44,281	64,299	60,614	3,685	--
58	--	--	--	697,110	18,822	45,476	64,298	60,614	3,684	--
59	--	--	--	651,634	17,594	46,703	64,297	60,614	3,683	--
60	--	--	--	604,931	16,333	47,964	64,297	60,614	3,683	--
61	--	--	--	556,967	15,038	49,259	64,297	60,415	3,882	--
62	--	--	--	507,708	13,708	50,590	64,298	60,415	3,883	--
63	--	--	--	457,118	12,342	51,956	64,298	60,415	3,883	--
64	--	--	--	405,162	10,939	53,358	64,297	60,415	3,882	--
65	--	--	--	351,804	9,499	54,799	64,298	60,415	3,883	--
66	--	--	--	297,005	8,019	56,279	64,298	60,205	4,093	--
67	--	--	--	240,726	6,500	57,799	64,299	60,205	4,094	--
68	--	--	--	182,927	4,939	59,359	64,298	60,205	4,093	--
69	--	--	--	123,568	3,336	60,962	64,298	60,205	4,093	--
70	--	--	--	62,606	1,690	62,606	64,296	60,205	4,091	--
	$1,609,658	$1,713,665	--	--	$1,759,087	$1,713,665	$3,472,752	$3,106,091	$367,655	$994

[a] Based on estimates supplied by Bechtel Corp.
[b] Includes funds for bond interest during construction.
[c] Excluding bonds outstanding upon which interest is provided from bond sale proceeds.

FEATHER RIVER PROJECT SCHEDULE 8A

FINANCIAL ANALYSIS

ROUTE 8A—BECHTEL'S PROPOSED HIGH LINE ROUTE TO DEVILS DEN AND COASTAL ROUTE TO TERMINAL AT GRANADA HILLS RESERVOIR

(000 omitted)

Project year	Construction funds required [a]	Bond issue required [b]	Cumulative bonds issued	Bonds outstanding [c]	Interest payable at 2.7 percent	Principal payable	Total bond service payable	Net revenue available from project [a]	General fund obligation	Excess net project revenues
1	$92,439	$99,420	$99,420	--	--	--	--	--	--	--
2	109,017	113,906	213,326	--	--	--	--	--	--	--
3	96,285	97,950	311,276	$7,321	$198	--	$198	--	$198	--
4	3,741	4,027	315,303	311,276	8,404	--	8,404	$833	7,571	--
5	30,411	32,337	347,640	311,276	8,404	--	8,404	1,789	6,615	--
6	47,592	49,202	396,842	311,276	8,404	--	8,404	2,697	5,707	--
7	15,698	15,969	412,811	349,930	9,448	--	9,448	2,955	6,493	--
8	3,750	3,923	416,734	412,811	11,146	--	11,146	4,127	7,019	--
9	27,614	29,391	446,125	412,811	11,146	--	11,146	5,791	5,355	--
10	22,545	23,583	469,708	422,457	11,406	--	11,406	6,608	4,798	--
11	24,760	25,188	494,896	422,457	11,406	$681	12,087	7,532	4,555	--
12	--	--	494,896	494,215	13,344	1,505	14,849	8,320	6,529	--
13	5,600	5,858	500,754	492,710	13,303	2,264	15,567	9,237	6,330	--
14	40,477	48,178	548,932	490,446	13,242	2,355	15,597	9,819	5,778	--
15	62,146	73,285	622,217	499,646	13,490	2,673	16,163	10,489	5,674	--
16	46,564	53,216	675,433	496,973	13,418	3,144	16,562	10,950	5,612	--
17	262,136	290,282	965,715	493,829	13,333	3,363	16,696	10,594	6,102	--
18	250,810	269,656	1,235,371	490,466	13,243	3,487	16,730	11,164	5,566	--
19	315,694	329,896	1,565,267	486,979	13,148	3,847	16,995	10,744	6,251	--
20	107,588	109,448	1,674,715	517,006	13,959	4,171	18,130	11,240	6,890	--
21	--	--	1,674,715	1,647,225	44,475	4,527	49,002	30,743	18,259	--
22	--	--	1,674,715	1,642,698	44,353	4,649	49,002	34,669	14,333	--
23	1,424	1,533	1,676,248	1,638,049	44,227	4,836	49,063	37,701	11,362	--
24	4,984	5,213	1,681,461	1,633,213	44,097	5,487	49,584	41,450	8,134	--
25	7,120	7,243	1,688,704	1,627,726	43,949	6,457	50,406	45,015	5,391	--
26	--	--	1,688,704	1,635,258	44,152	7,252	51,404	47,489	3,915	--
27	1,424	1,533	1,690,237	1,628,006	43,956	10,965	54,921	48,613	6,308	--
28	8,344	8,728	1,698,965	1,617,041	43,660	14,656	58,316	51,591	6,725	--
29	12,168	12,378	1,711,343	1,602,385	43,264	19,373	62,637	54,563	8,074	--
30	--	--	1,711,343	1,605,651	43,353	21,387	64,740	57,268	7,472	--
31	--	--	--	1,584,264	42,775	21,965	64,740	57,553	7,187	--
32	--	--	--	1,562,299	42,182	22,558	64,740	61,431	3,309	--
33	--	--	--	1,539,741	41,573	23,191	64,764	63,713	1,051	--
34	--	--	--	1,516,550	40,947	23,901	64,848	65,493	--	$645
35	--	--	--	1,492,649	40,302	24,667	64,969	65,736	--	767
36	--	--	--	1,467,982	39,636	25,327	64,963	65,545	--	582
37	--	--	--	1,442,655	38,952	26,039	64,991	64,699	292	--
38	--	--	--	1,416,616	38,249	26,910	65,159	64,780	379	--
39	--	--	--	1,389,706	37,522	27,885	65,407	64,861	546	--
40	--	--	--	1,361,821	36,769	28,637	65,406	64,936	470	--
41	--	--	--	1,333,184	35,996	29,411	65,407	64,387	1,020	--
42	--	--	--	1,303,773	35,202	30,205	65,407	64,468	939	--
43	--	--	--	1,273,568	34,386	31,021	65,407	64,546	861	--
44	--	--	--	1,242,547	33,549	31,859	65,408	64,627	781	--
45	--	--	--	1,210,688	32,689	32,718	65,407	64,978	429	--
46	--	--	--	1,177,970	31,805	33,602	65,407	64,779	628	--
47	--	--	--	1,144,368	30,898	34,509	65,407	64,779	628	--
48	--	--	--	1,109,859	29,966	35,441	65,407	64,779	628	--
49	--	--	--	1,074,418	29,009	36,398	56,407	64,779	628	--
50	--	--	--	1,038,020	28,027	37,380	65,407	64,779	628	--
51	--	--	--	1,000,640	27,017	38,390	65,407	64,579	828	--
52	--	--	--	962,250	25,981	39,426	65,407	64,579	828	--
53	--	--	--	922,824	24,916	40,491	65,407	64,579	828	--
54	--	--	--	882,333	23,823	41,584	65,407	64,579	828	--
55	--	--	--	840,749	22,700	42,707	65,407	64,579	828	--
56	--	--	--	798,042	21,547	43,860	65,407	64,379	1,028	--
57	--	--	--	754,182	20,363	45,045	65,408	64,379	1,029	--
58	--	--	--	709,137	19,147	46,260	65,407	64,379	1,028	--
59	--	--	--	662,877	17,898	47,509	65,407	64,379	1,028	--
60	--	--	--	615,368	16,615	48,792	65,407	64,379	1,028	--
61	--	--	--	566,576	15,298	50,109	65,407	64,180	1,227	--
62	--	--	--	516,467	13,945	51,462	65,407	64,180	1,227	--
63	--	--	--	465,005	12,555	52,852	65,407	64,180	1,227	--
64	--	--	--	412,153	11,128	54,279	65,407	64,180	1,227	--
65	--	--	--	357,874	9,663	55,744	65,407	64,180	1,227	--
66	--	--	--	302,130	8,158	57,250	65,408	63,970	1,438	--
67	--	--	--	244,880	6,612	58,796	65,408	63,970	1,438	--
68	--	--	--	186,084	5,024	60,383	65,407	63,970	1,437	--
69	--	--	--	125,701	3,394	62,013	65,407	63,970	1,437	--
70	--	--	--	63,688	1,720	63,688	65,408	63,970	1,438	--
	$1,600,331	$1,711,343	--	--	$1,667,866	$1,711,343	$3,379,209	$3,145,179	$236,024	$1,994

[a] Based on estimates supplied by Bechtel Corp.
[b] Includes funds for bond interest during construction.
[c] Excluding bonds outstanding upon which interest is provided from bond sale proceeds.

FEATHER RIVER PROJECT SCHEDULE 10A

FINANCIAL ANALYSIS

ROUTE 10A—BECHTEL'S PROPOSED HIGH LINE ROUTE TO QUAIL LAKE TERMINATING IN GRANADA HILLS RESERVOIR

(000 omitted)

Project year	Construction funds required [a]	Bond issue required [b]	Cumulative bonds issued	Bonds outstanding [c]	Interest payable at 2.7 percent	Principal payable	Total bond service payable	Net revenue available from project [a]	General fund obligation	Excess net project revenues
1	$95,828	$103,068	$103,068	--	--	--	--	--	--	--
2	115,368	120,553	223,621	--	--	--	--	--	--	--
3	110,658	112,571	336,192	$7,321	$198	--	$198	--	$198	--
4	3,741	4,027	340,219	336,192	9,077	--	9,077	$798	8,279	--
5	30,431	32,359	372,578	336,192	9,077	--	9,077	1,752	7,325	--
6	47,619	49,220	421,798	336,192	9,077	--	9,077	2,660	6,417	--
7	15,745	16,017	437,815	374,846	10,121	--	10,121	2,947	7,174	--
8	3,750	3,923	441,738	437,815	11,821	--	11,821	4,219	7,602	--
9	27,614	29,391	471,129	437,815	11,821	--	11,821	5,782	6,039	--
10	28,145	29,440	500,569	447,461	12,081	--	12,081	6,599	5,482	--
11	30,360	30,885	531,454	447,461	12,081	$706	12,787	7,530	5,257	--
12	--	--	531,454	530,748	14,330	1,577	15,907	8,318	7,589	--
13	--	--	531,454	529,171	14,288	2,442	16,730	8,972	7,758	--
14	34,877	42,481	573,935	526,729	14,221	2,539	16,760	9,824	6,936	--
15	62,146	73,285	647,220	524,190	14,153	2,861	17,014	9,993	7,021	--
16	46,564	53,216	700,436	521,329	14,076	3,337	17,413	10,962	6,451	--
17	141,888	155,661	856,097	517,992	13,996	3,551	17,547	10,606	6,941	--
18	145,331	156,414	1,012,511	514,441	13,890	3,637	17,527	11,176	6,351	--
19	212,825	222,574	1,235,085	510,804	13,792	4,054	17,846	10,763	7,083	--
20	200,882	204,356	1,439,441	509,208	13,748	4,439	18,187	11,259	6,928	--
21	--	--	1,439,441	1,410,298	38,078	4,857	42,935	29,281	13,654	--
22	--	--	1,439,441	1,405,441	37,947	4,988	42,935	33,083	9,852	--
23	5,584	5,995	1,445,436	1,400,453	37,812	5,123	42,935	35,634	7,301	--
24	17,337	18,076	1,463,512	1,395,330	37,674	5,720	43,394	38,420	4,974	--
25	24,936	25,367	1,488,879	1,392,252	37,591	6,696	44,287	43,862	425	--
26	--	--	1,488,879	1,432,352	38,673	7,498	46,171	43,409	2,762	--
27	5,156	5,535	1,494,414	1,424,854	38,471	9,585	48,056	44,400	3,656	--
28	19,205	20,031	1,514,445	1,415,269	38,212	11,814	50,026	46,670	3,356	--
29	27,636	28,114	1,542,559	1,406,097	37,964	15,049	53,013	49,515	3,498	--
30	--	--	--	1,442,086	38,936	18,240	57,176	51,319	5,857	--
31	--	--	--	1,423,846	38,444	18,732	57,176	51,472	5,704	--
32	--	--	--	1,405,114	37,938	19,238	57,176	54,749	2,427	--
33	--	--	--	1,385,876	37,149	20,119	57,268	56,952	316	--
34	--	--	--	1,365,757	36,875	20,684	57,559	58,678	--	$1,119
35	--	--	--	1,345,073	36,317	31,668	57,985	58,921	--	936
36	--	--	--	1,323,405	35,732	22,253	57,985	58,730	--	745
37	--	--	--	1,301,152	35,150	22,937	58,087	57,884	203	--
38	--	--	--	1,278,215	34,512	23,959	58,471	57,965	506	--
39	--	--	--	1,254,256	33,864	25,171	59,035	58,046	989	--
40	--	--	--	1,229,085	33,185	25,850	59,035	58,121	914	--
41	--	--	--	1,203,235	32,487	26,548	59,035	57,572	1,463	--
42	--	--	--	1,176,687	31,771	27,264	59,035	57,653	1,382	--
43	--	--	--	1,149,423	31,034	28,001	59,035	57,731	1,304	--
44	--	--	--	1,121,422	30,278	28,757	59,035	57,812	1,223	--
45	--	--	--	1,092,665	29,502	29,533	59,035	57,893	1,142	--
46	--	--	--	1,063,132	28,705	30,330	59,035	57,704	1,331	--
47	--	--	--	1,032,802	27,886	31,149	59,035	57,704	1,331	--
48	--	--	--	1,001,653	27,045	31,990	59,035	57,704	1,331	--
49	--	--	--	969,663	6,181	32,854	59,035	57,704	1,331	--
50	--	--	--	936,809	25,294	33,741	59,035	57,704	1,331	--
51	--	--	--	903,068	24,383	34,652	59,035	57,494	1,541	--
52	--	--	--	868,416	23,447	35,588	59,035	57,494	1,541	--
53	--	--	--	832,828	22,486	36,549	59,035	57,494	1,541	--
54	--	--	--	796,279	21,500	37,535	59,035	57,494	1,541	--
55	--	--	--	758,744	20,486	38,549	59,035	57,494	1,541	--
56	--	--	--	720,195	19,445	39,590	59,035	57,294	1,741	--
57	--	--	--	680,605	18,376	40,659	59,035	57,294	1,741	--
58	--	--	--	639,946	17,279	41,756	59,035	57,294	1,741	--
59	--	--	--	598,190	16,151	42,884	59,035	57,294	1,741	--
60	--	--	--	555,306	14,993	44,042	59,035	57,294	1,741	--
61	--	--	--	511,264	13,804	45,231	59,035	57,095	1,940	--
62	--	--	--	466,033	12,583	46,452	59,035	57,095	1,940	--
63	--	--	--	419,581	11,329	47,706	59,035	57,095	1,940	--
64	--	--	--	371,875	10,041	48,994	59,035	57,095	1,940	--
65	--	--	--	322,881	8,718	50,317	59,035	57,095	1,940	--
66	--	--	--	272,564	7,359	51,676	59,035	56,885	2,150	--
67	--	--	--	220,888	5,964	53,071	59,035	56,885	2,150	--
68	--	--	--	167,817	4,531	54,504	59,035	56,885	2,150	--
69	--	--	--	113,313	3,059	55,976	59,035	56,885	2,150	--
70	--	--	--	57,337	1,548	57,337	58,885	56,885	2,000	--
	$1,453,626	$1,542,559	--	--	$1,520,037	$1,542,559	$3,062,596	$2,832,292	$233,104	$2,800

[a] Based on estimates supplied by Bechtel Corp.
[b] Includes funds for bond interest during construction.
[c] Excluding bonds outstanding upon which interest is provided from bond sale proceeds.

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